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Control and prevention of ice formation and accretion on heat exchangers for ventilation systems

Rahimi, Maral; Afshari, Alireza

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Editors: *Marcel Loomans, Eindhoven University of Technology*
Marije te Kulve, Maastricht University

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[Paper_ID366](#) **LONG-TERM EXPOSURE TO RESIDENTIAL RADON AND RISK OF SKIN CANCER**
non-melanoma skin cancer; residential radon;
Bräuner, V. Loft, S., Sørensen, M., Jensen, A., Andersen, CE, Ulbak, K., Pedersen, C., Tjønneland, A., Kjær, S., Raaschou-Nielsen, O., Raaschou-Nielsen, O.,
Although exposure to UV radiation is the major risk factor for skin cancer, theoretical models suggest that exposure to radon can contribute to risk and this is supported by ecological studies from the UK.
We sought to confirm or refute this using a prospective cohort design and long-term residential radon exposure.
During 1993-1997, we recruited 57,053 Danish persons and collected baseline information. We traced residential addresses of the cohort members and calculated radon concentrations at each address lived in from 1 January 1971 until censor date using geology and housing information. Cox proportional hazards models were used to estimate incidence rate-ratios (IRR) and 95 % confidence intervals (CI) for the risk associated with radon exposure.
Over a follow-up of 13.6 years of 51,445 eligible subjects, there were 3,243 cases of basal cell carcinoma (BCC), 317 cases of squamous cell carcinoma (SCC) and 329 cases of malignant melanoma (MM). The adjusted IRRs per 100 Bq/m² increase in residential radon levels for BCC, SCC and MM were 1.14 (95% CI: 1.03, 1.27), 0.90 (95% CI: 0.70, 1.37) and 1.08 (95% CI: 0.77, 1.50), respectively.
Long-term residential radon exposure may contribute to development of basal cell carcinoma of the skin.

[Paper_ID367](#) **ASSESSMENT OF OVERHEATING RISK IN DWELLINGS**
Dwellings; Overheating; Thermal comfort
Hamdy Mohamed, M.H., Hensen, J.L.M.



Overheating in buildings is identified as an essential cause of several problems ranging from thermal-discomfort and productivity reduction to illness and death. The aim of this study is to assess the overheating risk in dwellings considering the diversity in dwelling designs and operations as well as the expected changes in climate. The overheating risk in thousands dwelling cases is assessed for current and future climate scenarios by using high-resolution dynamic thermal modelling and a new-defined performance indicator called indoor overheating degree (IOD). The dwelling cases represent 9,216 possible combinations of archetypes, orientations, fabric-characteristics, shading options, ventilation rates, internal-heat gains, and adaptation opportunities consistent with the characteristics of the Dutch dwelling stock from 1964 to 2012. The results show that for a given climate scenario, there is a significant difference in overheating risk in dwellings. The difference will increase in the future as global warming continues mainly because of the reduction in natural cooling potential. Dwellings with high solar-heat gains (e.g., detached houses with a large inefficient-shaded glazing area) and/or with low-heat transmissions (e.g., highly-insulated/small-facade apartments) are at higher risk of overheating than others. Adaptation interventions should be taken quickly for protecting those more sensitive dwelling to climate change.

[Paper ID368](#)

INDOOR AIR QUALITY IN GREEN BUILDING CERTIFICATIONS

IAQ criteria; Rating;

Wei, WW. , Ramalho, O , Mandin, C ,

Green building aims to construct energy-efficient, healthy, and productive buildings that reduce the significant impact of buildings on urban life and the global environment. Many countries worldwide in the past two decades have developed green building schemes. The objectives of this paper are to review recent green building certifications and their schemes worldwide and to analyze how and to what extent IAQ is taken into account. 31 certifications from 30 countries worldwide (13 in Asia, 9 in Europe, 5 in Americas, 2 in Oceania, and 1 in Africa) were retrieved comprising 64 schemes. 55 were considered for the detailed review. IAQ is included in all of the certifications. The global average contribution of IAQ in green building certifications is 7.5%. A large variety of compounds, e.g., VOCs, formaldehyde, and CO₂; are targeted. All of the certifications propose ventilation for IAQ management, whereas 77% and 65% of the certifications propose emission source control and indoor air measurement, respectively. This paper has shown the need for transparency to allow the comparison and normalization of green building schemes. Opportunities to harmonize the different approaches used worldwide should be pursued in the future.

[Paper ID370](#)

INFILTRATION INDUCED CONTAMINANT TRANSMISSION AND CROSS-INFECTION INTRA SINGLE RESIDENTIAL BUILDING

Air infiltration; Contaminant transmission; Cross-infection risk assessment

WU, Y.W.. , NIU, J.



Airborne transmission is an important spread mode of infectious respiratory diseases. A transmission route induced by air infiltration via cracks of closed windows and doors attracted our attentions. In the present study, the infiltration caused horizontal contaminant transport between flats was studied using multi-zone model and the pressure boundary condition outside building facades was obtained from our previous wind tunnel experiments. The cross-infection risks were assessed using Wells-Riley model. The influence of air tightness of windows and doors on air change and contaminant transmission were analysed. It is found that, windward side flats has higher infiltration rate and has lower indoor contaminant level than leeward side flats. Both increasing window and door leakage could boost the infiltration rate, but only enlarge window leakage could reduce indoor contaminant level. The infectious risk in a zone with long-term infected source can be significantly higher than that with short-term source. Properly enhancing door tightness and reducing window tightness could control infiltration induced contaminant transmission in residential building.

[Paper ID371](#)

REDUCTION OF ALDEHYDES AND TERPENES IN PINE WOOD BY MICROBIAL ACTIVITY

Pseudomonas sp.; Terpenes; VOC-reduction

Widhalm, B.,

Aldehydes and terpenes are natural components in softwoods and also the most frequently emitted volatile organic compounds (VOC) in wood-processing industry. Production processes of wood composites initiate and increase the formation of VOC emissions. Aldehydes and terpenes are classified as injurious to health and hazardous to the environment. The present work aims at the reduction of pentanal and hexanal (aldehydes) as well as α -, β -pinene and delta 3-carene (terpenes) in pine wood particles. In preliminary tests under laboratory conditions bacterial species mainly belonged to the genus, which are suitable for the utilization of aldehydes and pinene as single carbon source in a liquid culture medium, were selected. Due to the results from liquid culture tests, a bacterial mixture was inoculated on pine wood particles and incubated at room temperature for six days. SPME/GC-MS analysis of emitted volatiles indicates a total reduction of aldehydes and a partial degradation of terpenes in comparison to untreated wood particles. Tests on laboratory scale should provide a basis for future studies and tests on pine wood strands to be used for the production of oriented strand boards on technical or pilot scale.

[Paper ID372](#)

AN ALTERNATIVE VENTILATION SYSTEM FOR OPERATING THEATRES: AN EXPERIMENTAL AND CFD STUDY ON THE PERFORMANCE OF A LOCAL VENTILATION DEVICE

Air quality; Local ventilation; Operating theatre

Loogman, J.G.H., Visser, I.M. de, Loomans, M.G.L.C., Kort, H.S.M., Sanden, N.P.M. van der, Noor, R.J.R., Burgmeijer, E.R.T., Wieren, P. van,



A local operating theatre ventilation device which ventilates the wound area only, was investigated applying a parameter study. The ventilation device is combined with a blanket which lies over the patient during the operation. Two configurations were studied: configuration 1 where HEPA-filtered air was supplied around and parallel to the wound area and configuration 2 where HEPA-filtered air was supplied from the top surface of the blanket, perpendicular to the wound area. The objective of the parameter study was to identify critical parameters.

A simplified setup, which consisted of a sideways contaminated airflow and a HEPA-filtered airflow, was studied by experiments and CFD simulations. Particle concentrations ($=0.5\mu\text{m}$) were measured at the wound, relative to a non-ventilated situation with only sideways contaminated airflow ($N=30$ per series; expressed in %). The effect of supply velocity, temperature and contaminant velocity were investigated.

In isothermal conditions relative particle concentrations of 0-11% and 0-1% were measured for configuration 1 and 2 with a supply velocity of 0.40m/s and 0.30m/s respectively. However, differences between both configurations were not significant. Furthermore, configuration 1 was more sensitive to lower supply velocities ($P<0.04$) and higher supply temperatures ($P<0.04$). CFD simulations showed similar trends, although absolute values were more positive.

[Paper ID374](#)

CROSS-INFECTION IN A HOSPITAL WARDROOM WITH INDIVIDUAL RETURN OPENINGS

CFD simulation; Cross-infection; Turbulent-mixing ventilation

Sadrizadeh, Sasan. , Holmberg, Sture

This article considers the role of individual return openings in controlling the spread of infection in a two-bed hospital ward. It proposes a simple and economical ventilation design capable of reducing cross-infection risk. A two-bed hospital ward ventilated by a ceiling-level low velocity diffuser was considered. Computational fluid dynamics analysis was used to simulate and compare particle removal efficiency of return openings. Different particle sizes were considered for simulating pathogenic contaminants and their concentration was calculated in patient breathing zones. A range of return opening velocities was tested. According to the results, boosting local individual return opening air velocity could effectively increase ventilation performance and particle removal efficiency could be significantly improved. The proposed personal exhaust opening system can be potentially applied in retrofitting practice in existing hospital wards with high cost effectiveness as compared to a full-scale renovation.

[Paper ID376](#)

DOES RELEASE POSITION OF BACTERIA-CARRYING PARTICLES INFLUENCE CONTAMINANT DISTRIBUTION IN AN OPERATING ROOM?

contaminant distribution; operating room; Particle launch position

Sadrizadeh, Sasan. , Holmberg, Sture , Ljungqvist, L , Reinmüller, R



It is generally accepted that human skin is a source of bacterial dispersal and the most common cause of infection in sensitive indoor surgical environments such as operating rooms (ORs). Airborne particles carrying microorganisms are dispersed from the whole body, but with different release rates. Previous studies show that particle dispersal was occurring mainly from the lower part of the body, especially from the perineal area. Whether the release position influences particle distribution in the surgical area has not been well known.

In this paper, two different particle launch positions, one from the head and neck and one from the perineum region and feet, were compared. Computational fluid dynamics (CFD) technique was employed to solve the governing equations for airflow and particle distribution.

The results indicate that particles released from the lower part of the body might easily rise by buoyancy forces. Several vortices generated by the main OR ventilation system may also bring particles from the lower part of the OR to the surgical area and increase the risk of infection.

[Paper ID378](#)

THERMAL ENVIRONMENT IN FINNISH LOW-ENERGY AND CONVENTIONAL HOUSES

conventional house; Low-energy house; perceived thermal environment

Holopainen, A. R. V.,

We assessed the thermal environment conditions of eight recently built low-energy houses and twelve older conventional Finnish houses. Room and outdoor air temperatures, as well as relative humidity, were measured from June 2012 to September 2013. We evaluated perceived thermal environment using a questionnaire during the heating and cooling seasons, and compared the measured and perceived thermal environments of the low-energy and conventional houses. The mean room temperature was 21.3 °C (19.8-22.5 °C) in the low-energy houses and 21.6 °C (18.1-26.4 °C) in the conventional houses during the winter. In the summer, the mean room temperature was 22.8 °C (21.9-23.8 °C) in the low-energy houses and 23.3 °C (21.4-26.5 °C) in the conventional houses. There were no statistically significant differences between the mean room temperature and relative humidity of the low-energy and conventional houses. The occupants in the low-energy houses perceived their indoor environment quality as slightly better than those in the conventional houses. The measurements and the questionnaire surveys showed that a good thermal environment was achievable in both the low-energy and the conventional houses.

[Paper ID380](#)

ASSOCIATION BETWEEN CO₂ CONCENTRATION AND AIR CHANGE RATE IN DANISH DAY-CARE CENTRES AND SHORT TERM SICK LEAVE AMONG CHILDREN.

absenteeism; child care; ventilation

Kolarik, BAK. , Jovanovic Andersen, ZJA , Hoy Engelund, EHE , Bräuner, ELB



Scandinavian children spent a large percentage of each day in public care. Children attending day-care centres (DCCs) have increased risk of respiratory and gastrointestinal infections compared to those that stay home, which has large social-economic consequences. The aim of the present study was to investigate whether there is an association between ventilation in day-care centres and sick leave among children due to infectious disease. Data on child sick leave within an 11 week period was obtained for 1206 children attending 20 DCCs. Ventilation measurements included three proxies of ventilation: air exchange rate (ACR) measured with the decay method and with perfluorocarbon tracer gas (PFT) method (both measured only in nursery part of the DCCs; 635 children), and CO₂ concentration measured over a 1-week period (measured in both nursery and in some kindergarten parts of DCCs). The mean concentration of CO₂ was 652 ppm, exceeding 1000 ppm in only one DCC. A statistically significant inverse relationship between number of sick days among nursery children and ACR measured with decay method was found for crude and adjusted analysis. Significant association was also found between CO₂ concentrations measured in nurseries and kindergartens and children's sick leave days.

[Paper ID381](#)

BEHAVIOUR OF A PHOTOCATALYTIC OXIDATION (PCO) LAYER APPLIED ON THE WALLS AND THE CEILING OF A REAL TEST ROOM: IMPACT OF SOME KEY FACTORS

PCO; Real test room; Titanium dioxide

ALESSI, FA. , Negri, NN

Many studies about photocatalytic oxidation (PCO) have been carried out in laboratories. They use an inert test chamber with a low volume, a controlled temperature and humidity, and a constant injection of specific gases. In these "ideal conditions", several key factors (KF) able to modify the PCO, have been identified in the literature. However few studies have implemented such systems at "real scale" to understand how a photocatalyst layer reacts in a real test room? And what are the main PCO key factors? In this article, a titanium dioxide layer (TiO₂), in contact with the indoor air (IA), was embedded in a real test room (TR) of an experimental house. This photocatalyst was one of the four layers of a passive system (PS) designed to improve the indoor air quality (IAQ). A specific IAQ monitoring in the TR assessed the removal rate of the total volatile organic compounds (TVOC), as well as formaldehyde (HCHO) as a possible intermediate, and the nanoparticle (NP) emissions. This was compared with a reference room (RR) without the PS which was not equipped with. Both for the TVOC and HCHO concentration, the results showed a significant impact mainly for following KF: UVA, humidity, temperature.

[Paper ID382](#)

MICROBIAL SAMPLING IN BUILDING SURVEYS: WHAT AND WHY ARE WE SAMPLING?

Building ecology; Building microbiome; Moisture damage

Nunez, MN. , Mattsson, JM



Buildings are the main arena where human life unfolds. Numerous microbial spores and fragments from both the outdoor environment and building occupants (humans, their pets and plants) settle on surfaces, while others become airborne or are removed by surface cleaning and steadily intricate HVAC systems. There is always a background level of microbial fragments and spores in buildings. But do buildings have their own microbiome? And what happens when this microbiome is altered?

In order to address building issues, we need to characterize the building microbiome in every case, and critically contrast it with other microbiomes sharing the same building environment. Differentiating microbial sources and sinks is necessary in order to set the building microbiome back to normal levels. Cleaning and disinfection of surfaces is not an effective measure when the surface is a microbial sink, and not a source.

[Paper ID383](#)

FACTORS AFFECTING ENDOTOXIN CONCENTRATIONS IN INDOOR AIR — A REVIEW

Concentration; Endotoxin; Indoor air

Salonen, Mrs. , Duchaine, Mrs , Létourneau, Mr , Mazaheri, Miss , Laitinen, Mrs , Clifford, Mr , Lappalainen, Mrs , Reijula, Mr , Morawska, Mrs ,

As endotoxin exposure indoors has many known effects on human health, it is important to determine the factors that contribute to endotoxin levels in indoor air. This review concerns the current knowledge on the environmental factors that may affect endotoxin levels in indoor air. The material in this literature review consists of peer-reviewed journal articles. The relevant literature was located using Google and Pubmed. The search terms were based on individual words and combinations such as endotoxins, indoor environment, environmental characteristics, airborne endotoxins, and bioaerosols.

Analysis of the data confirmed strong scientific evidence that the presence of pets (especially dogs), relative humidity of indoor air and tobacco smoking affect the concentrations of endotoxins in indoor air. However, the findings regarding the effect of relative humidity and tobacco smoking on endotoxin levels are contradictory ? some studies found no relationship with concentrations of endotoxins in indoor air. There are also studies reporting an association between moisture/dampness damage, moldy odor, number of occupants, presence of carpets, and temperature, and the concentrations of endotoxins in indoor air.

Literature findings show inconsistency concerning the effect of several environmental factors on endotoxin indoor levels. Additional studies are needed.

[Paper ID384](#)

CUMULATIVE INDOOR EXPOSURES TO SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs) IN FRENCH DWELLINGS: PROGRESS OF THE ECOS PROJECT.

Indoor exposure; risk assessment; SVOC

Glorennec, P. ,



The ECOS project aims at assessing the Public Health risk posed by semi-volatile compounds indoor with a risk assessment framework, comprising substances and hazard identification, dose response assessment, exposure assessment and finally risk characterisation. SVOCs were identified through a literature survey. Hazardous substances were then ranked on the basis of measured concentrations and toxicity. 50 of top-ranked chemicals that were measurable with GC/MS were selected for this project. Corresponding GC/MS analytical methods were developed and implemented on nationwide of representative samples of settled dust (n=145) and airborne particles (PM) (n=285). Many SVOCs were detected and many have common health effects. Frequently detected SVOCs have then been grouped by common toxic mode of action. Comparable benchmark doses are calculated for reprotoxic effects (decrease of testosterone synthesis) and neurotoxic effects (neuronal death). Next step will be dose calculation from contamination data. The final step of risk characterization, will combine exposure doses and cumulative reference values to produce risk indicators. The originality of this project is 1) inclusion of SVOCs from different chemical families 2) specific analytical developments, 3) nationwide representative samples, and 4) cumulative exposure and risk assessment. First results indicate that several SVOCs present indoors have common mode of action.

[Paper ID385](#)

INDOOR AIR QUALITY IN PRIMARY SCHOOLS: PRELIMINARY RESULTS OF THE ARIA PROJECT

Children; Indoor air quality; Schools

Cavaleiro-Rufo, J. , Madureira, J , Paciência, I , Pereira, C , Teixeira, J P , Slezakova, K , Pereira, M C , Pinto, M , Moreira, A , Oliveira Fernandes, E , Oliveira Fernandes, E ,

Children spend a large part of their time at school, which might be reflected as a long term exposure to indoor air pollutants, possibly having a considerable impact on their health with an increased risk for developing asthma and allergies. The indoor air quality parameters (IAQ) of 10 primary schools were measured, including total volatile organic compounds (TVOC), formaldehyde, acetaldehyde, O₃, NO₂, PM₁₀, PM_{2.5}, ultrafine particles (UFP), bacteria and fungi concentrations. In addition CO₂, temperature, relative humidity (RH) levels were also assessed. The indoor average concentration for the 10 schools is 251 ±141 µg/m³ for TVOC; 18.1 ±7.1 and 7.8 ±2.4 µg/m³ for formaldehyde and acetaldehyde, respectively; 6.5 ±11.6 µg/m³ for O₃; 20.8 ±15.6 µg/m³ for NO₂ 65 ±30 and 38 ±24 µg/m³ for PM₁₀ and PM_{2.5}, respectively; 9.06 ±4.6 x10³ pt/cm³ for UFP; 2246 ±1577 and 1164 ±2130 CFU/m³ for bacteria and fungi, respectively; 1315 ±583 ppm for CO₂ 19.6 ±1.8 °C for temperature; and 56.7 ±8.9 % for RH. The results indicate that children in primary schools are subjected to large concentrations of CO₂ and exposed to increased levels of particulate matter and biological contaminants.

[Paper ID386](#)

TOWARDS PREDICTING THE SATISFACTION WITH INDOOR ENVIRONMENTAL QUALITY IN BUILDING PERFORMANCE SIMULATION

Building performance simulation; IEQ prediction; Occupant satisfaction

Loonen, R.. , Loomans, M.G.L.C. , Hensen, J.L.M. ,



Can computer simulations be used to predict occupant satisfaction and stimulate the design of energy-efficient, healthy buildings? This is the central question of this paper. In everyday practice, simulations are mostly used for building energy analysis and for limiting the occurrence of discomfort. There are, however, also opportunities for a more holistic prediction of indoor environmental quality (IEQ) with a focus on creating a positive experience for occupants. The aim of this position paper is to connect the field of building performance simulation (BPS) with IEQ research, by discussing the needs, recent advances and remaining challenges for prediction of overall occupant satisfaction. First, we highlight the importance of taking into account multiple performance criteria and physical domains. Based on a review of software tools, we then present a classification of their capabilities to simultaneously assess the various physical interactions. In the discussion that follows, we evaluate the merits and drawbacks of combined IEQ indices, and show how simulations can be used for predicting them. The paper concludes with an overview of research needs and possible directions for further development based on recent advances in the building performance simulation field.

[Paper_ID387](#)

MICROBIAL SAMPLING IN BUILDING SURVEYS: HOW TO CHOOSE A SAMPLING METHOD?

bacteria; fungi; microbiome

Reponen, Tiina. ,

A wide variety of sampling methods are available for assessing microorganisms in indoor environments. This paper presents a review of the traditional and modern sampling techniques available and will discuss the advantages and disadvantages of the choices available.

[Paper_ID389](#)

FROM RISK ASSESSMENT TO EXPOSURE REDUCTION

Intervention studies; risk assessment; VOCs

Khoury, F. , St-Jean, M. , Wong, J. , MacNeill, M. , Aubin, D. , Mallach, G.



Health Canada (HC) provides advice to Canadians on improving indoor air quality based on scientific evidence. This has traditionally centered on the development of Residential Indoor Air Quality Guidelines and Guidance (RIAQGs), which serve as recommendations, and are not enforceable under any legislation or regulatory action. Instead, they serve as the scientific rationale for further research, education and risk management aimed at improving indoor air quality.

Using the results of exposure studies and risk assessments, sources of exposure for which mitigation measures may be appropriate, were identified. Major sources included attached garages, traffic, and building materials. Subsequently, one intervention study examined methods to reduce infiltration of pollutants from attached garages into homes. The second addressed modifying ventilation patterns in schools to reduce the inflow of traffic-related pollutants. HC also initiated VOC emissions testing of products and building materials that led to involvement in a voluntary standard to limit VOCs in composite wood products.

Risk assessment and exposure science research have paved the way for targeted intervention studies and standards development. These will provide HC and its partners with the scientific basis to develop exposure reduction strategies or to provide a means to reduce exposure to indoor air pollutants.

[Paper ID390](#)

EARTH, WIND & FIRE - NATURAL AIR-CONDITIONING

Architectural Engineering; Climate responsive architecture; Natural Air-conditioning

Bronsema, B. , Dr. Bokel, R.M.J. , Dr. Ir. Spoel, W.H. van der,

The invention of air-conditioning in the early 20th century and its development since then has brought many advantages to mankind. In spite of this many people are not very satisfied with the indoor environment at their workplace. They complain about the air quality, the cold draught they experience, fan noise and dry air, causing dry eyes and throats, notorious elements of the so-called Sick Building Syndrome. As an experienced HVAC designer I asked myself if we could do better. Looking at termite hills, where termites closely work together, build their dwellings with natural air-conditioning but high Indoor Environmental Quality, a doctoral research was started. This implies a building designed as a 'climate machine', activated by gravity and the ambient energy of the earth mass, the wind, and the sun, metaphorically referred to as Earth, Wind & Fire. After 5 years of modelling, simulating, testing and validating it was demonstrated that natural air-conditioning in buildings is feasible. An air-conditioning without fans, nevertheless able to maintain an excellent indoor climate. This paradigm shift in air-conditioning not only promises an excellent Indoor Environmental Quality, but also an improved relationship of architect and engineer and much lower energy use of buildings.

[Paper ID391](#)

WHAT IS THE MOST APPROPRIATE METHOD TO ASSESS THERMAL COMFORT IN HOUSING?

Health; Housing; Thermal Comfort

Ormandy, D. , Ezratty, V



Introduction Underlying the concept of thermal comfort in housing is health. Dwellings are occupied for at least 8 hours each day, and longer by those most susceptible to high or low temperatures. It is this health protection that underlies the WHO guidance on thermal comfort in housing, giving a temperature range of 18-24°C. Although used for housing, the ASHRAE and ISO 2005 methods are inappropriate.

Discussion As well as practical problems associated with physically measuring temperature in housing, there is no standardised protocol, making it difficult to compare findings between studies.

Canvassing occupiers' perception of thermal comfort is the usual method used in surveys. The phrasing of questions may influence understanding, but, again, there is no standardised formulation. Also, some, such as the elderly, may not realise when the temperature could affect their health.

Another method is to adopt a proxy, calculating the energy efficiency of a dwelling using a recognised algorithm. However, this indirect and theoretical approach does not take account of the needs and resources of the household.

Conclusion Canvassing occupiers' perception of thermal comfort is probably the most useful for housing surveys, but may not be necessarily reliable for some susceptible groups.

[Paper ID392](#)

CONTROL AND PREVENTION OF ICE FORMATION AND ACCRETION ON HEAT EXCHANGERS FOR VENTILATION SYSTEMS

Heat exchangers; Ice formation; Passive and active prevention methods

Rahimi, Maral. , Afshari, Professor

In cold climates, the application of mechanical ventilation systems with heat recovery like are air-to-air exchangers is used for reducing energy consumption for heating buildings by transferring heat exhausted air to supply air. However, increase efficiency of heat exchanger results in lower exhaust air temperatures and Ice formation on heat exchanger fins, which can cause problem and is not favourable. Therefore, prevention and control of ice formation on heat exchangers is necessary. The existing methods are divided into two different methods: active and passive ice control methods. The active methods are e.g. bypass, recirculation, preheating. The passive methods relate to the surface characteristics of the heat exchanger fins as they have effect on ice formation in initial phase. All these methods have varying levels of success, cost, and effectiveness, which are depending on the heat exchangers operating condition and construction. Since, the active method are reducing efficiency of heat exchanger and the passive methods are not permanent solution it can be suggested that the optimum ice protection method may be a combination of both methods. The aim of this paper is to review and evaluate the current methods to provide new insight of concern for the ice formation problem.

[Paper ID393](#)

HOME ENVIRONMENT AND ASTHMA IN PORTUGUESE SCHOOLCHILDREN: A CASE-CONTROL STUDY

Asthma; Homes; Indoor air quality

Madureira, J. , Paciência, I , Rufo, J , Pereira, C , Teixeira, JP , Fernandes, EO



Many indoor air pollutants are known carcinogens or irritants, and have been associated with asthma. The aim of the current study is to compare the home environment of schoolchildren with and without asthma diagnosis.

A case-control study was performed including 38 schoolchildren with asthma and 30 healthy controls aged 9-11 years who attending primary schools in the Metropolitan area of Porto, Portugal. During the heating season, a walkthrough inspection was made to the homes of both groups using a checklist to collect information about the home environment, indoor spaces and occupants' behavior. The indoor assessment of volatile organic compounds, aldehydes, PM_{2.5}, PM₁₀, bacteria and fungi, CO₂, temperature and relative humidity levels was performed. Higher median concentrations were found at non-asthmatic children homes, except for α -pinene, styrene and bacteria. However, there were no significant differences in indoor air levels between homes of asthmatic and non-asthmatic children, except for d-limonene (10.6 $\mu\text{g}/\text{m}^3$ vs 15.6 $\mu\text{g}/\text{m}^3$, $p=0.013$). Identified emission sources included solvent-related emissions, household cleaning products and cigarette smoking.

Higher indoor air pollutant levels had been found at homes suggesting that differences in occupant behavior or in lifestyle could influence indoor air quality.

[Paper ID395](#)

OPTIMIZED DESIGN AND PERFORMANCE ASSESSMENT OF NATURAL VENTILATION SYSTEM USING WIND-CATCHER

Natural ventilation system; Optimized design; Wind catcher

WU, Y.W., NIU, J.

An energy efficient ventilation system, wind catcher natural ventilation system, was proposed in an enclosed bus station in Hong Kong. Numerical simulations were conducted to optimize the ventilation strategy. The numerical models were validated with an experiment of single-side natural ventilation. Three factors, wind catcher type, number and location, that would affect the ventilation performance, were analysed. The air change rate, age of air, pressure distribution and airflow organization were considered to evaluate the ventilation performance. One optimal design was chosen among four designs, and its annual performance was assessed. It is found that, one-sided wind catcher is preferred compared to four-sided wind catcher that would lead to the short circuit of airflow in large ventilation space. More wind catchers could contribute to larger air change rate. Inflow wind catcher near staircase should be avoided to prevent undesired reverse airflow from polluted lower bus stop floor to upper bus waiting floor. Among the four designs in the study, design 2 is the optimal design. And the annual ventilation performance of the optimal design is satisfactory.

[Paper ID397](#)

RELATIONSHIPS BETWEEN SOCIOECONOMIC FACTORS AND INDOOR AIR QUALITY IN FRENCH DWELLINGS

Housing; Indoor Air Quality; Socio-economic Status

Brown, TP., Dassonville, CD, Derbez, M, Ramalho, OR, Kirchner, SK, Crump, D., Mandin, CM,



INTRODUCTION: Few studies have analyzed the relationships between socioeconomic status (SES) and indoor air quality (IAQ). The aim of this study was to examine the relationships between SES and other factors and indoor air pollutant levels in French dwellings.

METHODOLOGIES: Levels of chemical, biological and physical parameters were measured over one week in a sample of 567 French dwellings between September 2003 and December 2005. Information on SES (household structure, educational attainment, income, and occupation), building characteristics, and occupants' activities (smoking, cooking, cleaning, etc.) were collected through administered questionnaires. Stepwise linear regression models were fitted to log-transformed concentrations on SES and other factors. Logistic regression was performed on fungal contamination data.

RESULTS AND DISCUSSION: Households with lower income were more likely to have higher concentrations of acetaldehyde, PM_{2.5}, and a positive fungal contamination index (FCI), but lower perchloroethylene concentrations. Formaldehyde concentrations were associated with occupational status of the head of the household and occupancy, and newly built buildings. Smoking was associated with increasing PM_{2.5} levels and the risk of a positive FCI. BTEX levels were associated with occupancy and having an attached garage.

CONCLUSIONS: Results show for the first time in France the relationships between SES and indoor air pollutants.

[Paper ID398](#)

IMPACT OF THERMAL RETROFIT ON INDOOR RADON EXPOSURE CONCENTRATION, FIRST RESULTS OF A MEASUREMENT CAMPAIGN IN BRITTANY, FRANCE

Housing; Indoor radon concentration; Thermal rehabilitation

Collignan, B., Mandin, C.M., Powaga, E.,

This study analysed the determinants of radon indoor concentrations in a large sample of dwellings, in particular considering the thermal retrofit. A radon measurement campaign in dwellings was conducted in Brittany region in France during 2011-2014. It was based on voluntary owners who carried out their own measurement using passive dosimeter. In addition, a questionnaire asking for building characteristics such as thermal retrofit, period of construction and type of foundation, was also filled in. More than 3,300 sets of data with both measurement results and questionnaire answers were collected.

Some building characteristics appeared to be associated with radon indoor concentration. The older were the dwellings, the higher were the radon concentrations. This is likely due to leakier ground floors in old dwellings (older concrete with more cracks). The types of foundation are also different depending on the age of dwellings and overall, for old dwellings, they are more favourable to the radon entry. Moreover, dwellings with thermal retrofit had in average a higher radon concentration than those without any renovation. This could be due to a decrease of air permeability of dwellings following this rehabilitation which is not systematically associated with a relevant management of the ventilation.

[Paper ID401](#)

HIGHLY SUSTAINABLE SCHOOLS: SOME DUTCH EXPERIENCES ABOUT IAQ AND PERCEIVED THERMAL COMFORT

IAQ; School ventilation; thermal comfort

Zeiler, W., Teeuwen, S., Bruggema, H.M., Bouwens, E



During the last decade different types of low-energy sustainable schools were built. However, a good thermal indoor environment and good indoor air quality should not be affected by energy consciousness should not affect them. Four recently finished sustainable schools were compared with the most recent Dutch comfort and IAQ guidelines for schools, Freshly Schools 2015, to find out the possible effects of the design concepts which were more focussed on sustainability than normal for schools. To be able to draw conclusions about indoor air quality and thermal comfort, the most important parameters were measured during one week. It showed that the design targets are not reached by the designs.

[Paper ID402](#)

ELDERLY CARE CENTERS INDOOR ENVIRONMENTS AND HEALTH

Allergic rhinitis; Elderly care centers; Indoor air quality

Mendes, AM. , Papoila, ALP , Carreiro-Martins, PCM , Bonassi, SB , Caires, IC , Palmeiro, TP , Aguiar, LA , Pereira, CP , Neves, PN , Mendes, DM , Mendes, DM , Botelho, AM , Neuparth, NN , Teixeira, JPT

From September 2012 to April 2013, the Portuguese version of BOLD questionnaire was administered to the elderly living in 21 elderly care centers (ECC) in Porto, Portugal, who gave their informed consent and were able to participate (n=143). Indoor environmental parameters (chemical and biological) were measured twice, during winter and summer in 135 areas within dining rooms, drawing rooms, medical offices and bedrooms. Mixed effects logistic regression models were used to study the association between the health questionnaire results and the monitored environmental parameters, adjusted for age, smoking habits, gender and number of years living in the ECC. Cough (23%) and sputum (12%) were the major respiratory symptoms, and allergic rhinitis (18%) the main self-reported illness. Overall PM_{2.5} median concentration was above the reference levels both in winter and summer seasons. Peak values of PM₁₀ TVOC, CO₂, bacteria and fungi exceeded the reference levels. In fact, older people exposed to PM₁₀ above the reference levels presented a higher odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1 – 7.2). Allergic rhinitis was the main self-reported illness. High levels of PM₁₀ were associated with a 3-fold odds of allergic rhinitis. No association were found between indoor environment and respiratory symptoms.

[Paper ID403](#)

EFFECTS OF EXPOSURE TO CARBON DIOXIDE AND HUMAN BIOEFFLUENTS ON HUMAN SUBJECTIVE RESPONSES

Carbon dioxide; Health symptoms, Subjective responses; Human bioeffluents, Indoor air quality

Zhang, XJ. , Wargocki, P. , Lian, ZW ,



The purpose of this study was to examine whether exposure to carbon dioxide (CO₂) with and without bioeffluents would result in the same levels of sensory discomfort and acute health symptoms. Five exposure levels were examined: reference with CO₂ at 500 ppm, pure CO₂ at 1,000 ppm and 3,000 ppm, and bioeffluents when CO₂ (generated metabolically) was at 1,000 ppm and 3,000 ppm. Twenty-five subjects were exposed in a low-emission stainless-steel climate chamber for 255 minutes in groups of five persons at a time. Subjective ratings were collected, physiological responses were monitored and cognitive performance was examined. Perceived air quality was not affected by exposures to CO₂ only. Exposures to bioeffluents including CO₂ significantly reduced perceived air quality and significantly increased the intensity of subjectively reported headache, fatigue, sleepiness and difficulty in concentrating. No effects on these or any other acute health symptoms were seen during exposures to CO₂ only. The present results show that CO₂ should not be considered as harmful at the levels likely to occur indoors, but that moderate to high concentrations of bioeffluents can cause air quality complaints and may result in an increased intensity of subjectively reported acute health symptoms that have a neurobehavioural origin.

[Paper ID404](#)

PHTHALATE PARTITIONING TO COTTON FABRICS

clothing; exposure; SVOC

Morrison, G. , Li, H. , Mishra, S. , Holtmeyer, C.

Semi-volatile organic compounds sorb effectively to many surfaces including fabrics. Clothing that is contaminated and subsequently worn may increase dermal exposure due to release of chemicals near the skin. In this study, we measured the 10-day sorptive partitioning of two phthalate esters with three different cotton fabric materials. Small squares of fabric from a cotton undershirt, tee-shirt and jeans were exposed at three different concentration of diethylphthalate (DEP) and di-n-butylphthalate (DnBP) at 25°C. We observed linear equilibrium isotherms for each compound and cloth material. Assuming that 10 days was sufficient to achieve equilibrium, partition coefficients normalized by fabric area, K_{area} , $[(\text{mass/fabric area})/(\text{mass/air volume})]$ and fabric volume, K_{vol} , $[(\text{mass/fabric volume})/(\text{mass/air volume})]$ were determined. DEP partition coefficients ($K_{area}; K_{vol}$) were for undershirt (208 m; 2.6×10^5), tee-shirt (246 m; 2.5×10^5) and jeans (411 m; 2.7×10^5). DnBP partition coefficients ($K_{area}; K_{vol}$) were for the undershirt (2850 m; 3.6×10^6), tee-shirt (3650 m; 3.7×10^6) and jeans (6580 m; 4.4×10^6). Wearing a full-set of these clothes at equilibrium with DnBP is effectively like concentrating $\sim 10,000$ m³ of contaminated air very close to the skin.

[Paper ID405](#)

THERMAL PERCEPTION DIFFERENCES IN A PRECINCT AND IMPLICATION FOR BUILDING OUTDOOR ENVIRONMENT DESIGN

Field measurement; Outdoor thermal perception; Physiological equivalent temperature (PET)

LIU, L.J.L. , NIU, N.J.L. , QIAN, Q.X.N. ,



Citizens wish to take more outdoor spaces with walking and other recreational activities, while they are frequently acquired uncomfortable thermal conditions especially in summer. Furthermore, high building densities lower the average wind speed at city scale. The conscientious use of building morphology to create local thermal comfort zone at selected spots in a large precinct is possible. This paper is a proof of concept study via real life continuous monitoring of the pedestrian level microclimatic parameters, include instantaneous wind speed, air temperature, globe temperature and humidity. Three outdoor locations on an existing campus were chosen and daily thermal perceptions had been evaluated using PET (Physiological equivalent temperature) and a PET based new index, thermally-perceivable environmental parameters' differences. The results presents that the wind speed and radiant temperature differences would make significant differences in local thermal perception. These indicate that wind amplification with shading at local area can acquire thermally comfortable perception of summer, even at a sunny day in a subtropical city. The findings can make clear to what extent the local thermal comfort is modified at sample days and be attributed to precinct planning.

[Paper ID406](#)

EP-OP METHOD FOR COST-BENEFIT ANALYSIS OF IMPROVED INDOOR CLIMATE AND REDUCED ENERGY CONSUMPTION IN OFFICE BUILDINGS: CASE STUDIES

Building energy performance; Cost-benefit analysis; Occupant productivity

Jurelionis, A.J.. ,

There are significant results reported in relation to indoor climate and performance of the office work. However, retrofitting of the existing HVAC systems or building envelope may be required in order to ensure good thermal comfort and air quality conditions in buildings and it may increase energy and maintenance costs as well. On the other hand, particular investment might have no effect on office work performance while having major impact on energy performance. This paper deals with assessment of occupant productivity and energy consumption in office buildings by using "EP-OP" (Energy Performance and Occupant Productivity evaluation) method. Five buildings in Lithuania were selected for the analysis and questionnaire survey of the occupants, thermal comfort measurements as well as energy performance analysis was performed. It revealed significant dissatisfaction by indoor climate which appears in both up-to-date (21%) and old-fashioned (81%) buildings and might lead to productivity losses in the range of 1% to 13%. Results presented in this study confirm that "EP-OP" method can be used efficiently in order to combine energy performance and human productivity analysis in office buildings.

[Paper ID407](#)

PHOTOCATALYTIC DEGRADATION OF TOLUENE, BUTYL ACETATE AND LIMONENE UNDER UV AND VISIBLE LIGHT

emission test chamber; Titanium dioxide; volatile organic compounds

Mull, B.. ,



Photocatalytic degradation of toluene, butyl acetate and limonene was investigated under UV LED light ($\lambda = 365$ nm) and blue LED light ($\lambda = 455$ nm). Experiments were done at indoor air concentration levels of 16-211 $\mu\text{g m}^3$ in 20 l emission test chambers under dynamic conditions. Ceramic tiles coated with pure and modified titanium dioxides were used as photocatalytic active material. Degradation of toluene, butyl acetate and limonene was obtained under UV light in a range of 31-96 % for all investigated coated tiles. Degradation under blue LED light could only be obtained for toluene and limonene in a range of 20-61 % for two modified samples.

[Paper ID408](#)

ADAPTING DWELLINGS TO PROTECT RESIDENTS FROM EXCESS HEAT

Existing dwellings; Health; Overheating

Ezratty, V. , Ormandy, D.

Introduction

Heat Wave Plans typically involve identifying and protecting groups during periods of high outdoor temperatures. There is also research on protective design for new dwellings. However, the majority of the housing stock already exists, and there is little guidance on building factors increasing the likelihood of overheating.

Method and Results

This project focused on identifying factors in existing dwellings that could contribute to overheating. The objective was to produce Guidance on dwelling assessment and possible solutions that would be useful in England and elsewhere in Europe.

Based on a review of the building factors and precautionary adaptations, the Guidance was drafted and then trialed by 22 experienced surveyors on a desktop exercise. All of the surveyors stated that the Guidance and Protocol was useful and would have helped them in their assessment.

Conclusion

As well as the positive assessment of the Guidance, the project demonstrated the need for such guidance and the need to develop long term programmes directed at the adaptation of existing dwellings.

[Paper ID411](#)

THE EFFECTS OF DIFFERENT TRANSITION SPACES THERMAL ENVIRONMENT ON ELDERLY PEOPLE'S COMFORT, PHYSIOLOGICAL PARAMETER AND BEHAVIOUR

Physiological parameter; Rest home; Transition space

Jiao, Y. ,



This study investigated the feature of four types transition spaces and their influence on elderly people's indoor thermal comfort, physiological parameter and behaviour in rest home by means of field study. Totally seven rest homes and 208 healthy old people over 60 in Shanghai, China were random chosen. Questionnaire and physical environment measurement includes indoor, transition space and outdoor environment parameters were taken simultaneously, then physiological measurement was carried out. Results indicate that the transition spaces' thermal environments and the elderly people's indoor thermal comfort varied by the space type. Among the four types of transition space, elderly tend to spend the longest time in activities in the transition space with great temperature difference in three-layer space with relatively higher temperature, lower humidity and lower air speed than indoor and outdoor temperature, humidity and air speed. Meanwhile, the field studies show that the temperature in transition space the elderly rely on for the longest activity is negative correlation with their Oxyhemoglobin Saturation and humidity is positive correlation with Oxyhemoglobin Saturation. Because the transition space the elderly prefer has larger temperature difference, the impact from the space on the elderly's health must be considered in the use and design process.

[Paper ID412](#)

A QUESTIONNAIRE SURVEY ON SLEEPING ENVIRONMENT UNDER DIFFERENT COOLING MODES IN MULTI-STORY RESIDENTIAL BUILDINGS OF SINGAPORE

Electrical fan; Questionnaire survey; Split air conditioner

Yang, B., Olofsson, OT

Good sleeping environment is important to guarantee person's health and performance. How to create comfortable and healthy sleeping environment with less energy use is worth exploring. Findings, based on one questionnaire survey on sleeping environment conditioned by different cooling modes (split system air conditioning unit, different kinds of electrical fans or purely natural ventilation), were reported. The study aimed to investigate human factors such as bedding and sleepwear use, using habits of different cooling devices, and human responses to thermal environment and air quality created by different cooling modes. 290 effective questionnaires were collected between June 2013 and May 2014, which were statistically analyzed. The results showed that most of the respondents prefer to use air conditioner for certain number of hours with relatively low temperature settings especially for respondents living below 5th floor. For respondents living above 10th floor, the number of hours using electrical fan or purely natural ventilation increase and their perceived air quality improve obviously. Respondents, who work outdoors during daytime, use less time for air conditioner with relatively high temperature setting. Elder respondents above 55 seldom use air conditioner.

[Paper ID413](#)

DIFFUSE CEILING VENTILATION AND THE INFLUENCE OF ROOM HEIGHT AND HEAT LOAD DISTRIBUTION

Diffuse ceiling ventilation; room air distribution; thermal load

Nielsen, P., Vilsbøll, R., Liu, L., Jensen, R. L.



Diffuse ceiling (inlet) ventilation is an air distribution system that supplies air from the entire ceiling surface, giving a low supply velocity. The flow pattern in the room is controlled by the heat sources. The system generates high mixing flow and the air velocities in the room are expected to be not much influenced by the flow rate to the room but dependent on the heat load. Previous studies have shown that diffuse ceiling ventilation has an ability to remove large heat loads without compromising the indoor climate. However, recent experiments indicate that the maximum accepted heat load decreases with a large room height and it decreases in connection with certain heat load distributions.

Room geometries and heat load distributions that are optimal for diffuse ceiling ventilation are discussed. A simplified design procedure is introduced.

[Paper ID414](#)

ON THE REDUCTION OF HEALTH EFFECTS FROM COMBINED EXPOSURE TO INDOOR AIR POLLUTANTS IN MODERN OFFICES: THE OFFICAIR PROJECT

indoor air quality; Office buildings; Risk assessment

Bartzis, J.G. , Kalimeri, K. , Barrero-Moreno, J. , Goelen, E. , Mandin, C. , Dimitroulopoulou, C. , Carrer, P. , Oliveira Fernandes, E. , Kotzias, D. ,

INTRODUCTION: Health complaints of office workers in modern offices due to the office environment may significantly impact their wellbeing and work performance.

METHODS: The OFFICAIR Project used laboratory analytical and toxicological studies, databases, monitoring and modeling tools and assessment methods towards an integrated approach in evaluating the health risk from indoor air pollution, focusing on modern office buildings.

RESULTS AND DISCUSSION: The indoor air quality (IAQ) in European modern offices was monitored in association with the evaluation of the workers' performance and their perception of comfort and IAQ. A clearer picture was generated regarding building characteristics in modern offices across Europe. New insight has been given on ozone terpene chemistry. A systematic study for evaluating IAQ health effects and their reduction via intervention measures was made and new tools have been developed in assessing exposure and health risk in modern offices and indoor microenvironments in general. The OFFICAIR Database can be used for estimating indoor air pollution and exposure in modern office buildings and other indoor microenvironments.

CONCLUSIONS: OFFICAIR is substantially contributing to a healthier life at work and helping to steer EU policies towards the better protection of building occupants by clarifying the mechanisms surrounding exposure conditions and effects.

[Paper ID415](#)

CONCENTRATION OF BIS(2-ETHYHEXYL) PHTHALATE ON THE SURFACE OF POLYVINYL CHLORIDE FLOORING

Bis(2-ethyhexyl) phthalate; Bleed out; Phthalate

Kim, HY Kim. , Tanabe, S.T



In order to reduce phthalates contamination and risk for infants in an indoor environment, it is important to identify contamination status and features of phthalates. In case of PVC flooring, even if there is no substance such as house dust, phthalates were bleed-outed on the surface of the PVC flooring. In addition, the research found that the phthalates on the PVC flooring would still remain, even though the mock-up dust on the PVC flooring is removed by using a vacuum cleaner. Therefore, the results of study predicted that it is impossible to completely remove all the phthalates remained on the surface of PVC flooring, despite of the fact that the dust deposited on the PVC flooring indoor is removed.

[Paper ID416](#)

BASIC STUDY ON THE LAWN SCHOOLYARD AND THE SCHOOL ACCIDENTS –STUDY ON THE DATA COLLECTED IN TOKYO METROPOLITAN ELEMENTARY SCHOOLS DURING 2005~2009-

Accidents in schools; Lawn laying; Schoolyard

Iwashita, G.I. ,

The data of accidents in the elementary schools in the ward areas of Tokyo, urban districts of Tokyo were linked with the penetration rate of lawned schoolyard of relevant areas in order to research the relation between accidents occurring at elementary schools and the lawn laying conditions. The data of accidents of elementary schools were obtained from the NAASH (National Agency for the Advancement of Sports and Health), and the period of analysis was set as 5 years from 2005 to 2009. The data of penetration rate of lawned schoolyard of relevant areas were obtained with questionnaire survey. While the penetration rate of lawned schoolyard of elementary schools in Tokyo metropolitan area was elevated from 2005 to 2009, the accident rate occurred on schoolyards in relevant area was decreased. The school accidents especially occurred during physical education, cocurricular sports club activity, and school events such as field day were significantly decreased. Lawn laying might have significant effects on diminution of accidents occurred on schoolyard.

[Paper ID417](#)

THE EFFECT OF A CEILING BASED COOLING JET ON WORK PERFORMANCE AND THERMAL COMFORT – A LABORATORY STUDY

Cooling jet; Thermal comfort; Work performance

Maula, H. , Koskela, H K , Varjo, J V , Hongisto, V H



Altogether, 29 participants (13 male and 16 female) were tested in an office laboratory with room air temperature 29.5 °C, relative humidity 20 % and supply air flow rate 280 l/s. Two thermal conditions were tested; no cooling jet and cooling jet with fresh supply air ($DT = -3.5$ °C and target velocity 0.8 m/s). A repeated measures design was used and the order of thermal conditions was counterbalanced. Clothing insulation and activity level were controlled. Work performance was measured with two cognitively different tasks (short-term memory task and working memory task). Whole body thermal comfort, local thermal comfort, symptoms and subjective performance ratings were assessed with questionnaires. No main effect on work performance was found. However, further analysis showed performance increment over time when cooling jet was provided. Thermal environment with the cooling jet was perceived to be better for whole body and local thermal comfort and perceived indoor air quality. Thermal environment with the cooling jet was perceived to be better for working efficiently for long time. However, participants reported more draught and irritation of eyes with the cooling jet. Open questionnaires about perception of cooling jet showed wide variety between participants.

[Paper_ID418](#)

EFFECT OF THERMAL ENVIRONMENTAL CONTROL IN SUMMER ON ENERGY CONSUMPTION AND SLEEP

Energy consumption; Sleep; Thermal environmental control

Honda, E. , Ikaga, Prof , Ohira, Dr. , Umishio, Mr.

The reduction of energy consumption in the Japanese residential sector is a pressing issue because of climate change. However, an excessive reduction in air conditioner use to save energy could create a poor sleep environment. Therefore, the purpose of this research was to elucidate the impact of air conditioning on both energy consumption and sleep during the summer. Eight healthy male university students participated in this study, which was conducted in August 2013. Three thermal environmental control scenarios were used: natural draft, air conditioner set at 26.0 °C (continuous operation), and air conditioner set at 28.0 °C (continuous operation). Energy consumption, indoor thermal environment, and sleep state were measured during the experiment. The energy consumption for using an air conditioner for 8 h was reduced by 0.03 kWh/day/m² by increasing the temperature setting from 26.0 to 28.0 °C. Furthermore, the range of the average standard new effective temperature during sleep was from 27.6 to 31.4 °C (the average temperature during sleep was from 26.5 to 29.8 °C) where both energy saving and high-quality sleep were achieved. The results of this study indicate lifestyle changes are possible that allow both energy saving and high-quality sleep.

[Paper_ID419](#)

WE ARE NOT ALONE! – MICROBIOMES IN CONTROLLED AND UNCONTROLLED BUILT ENVIRONMENTS.

cleanrooms; intensive care units; Viable controlled and uncontrolled microbiomes

Mahnert, AM. , Moissl-Eichinger, CM , Müller, HM , Probst, AJP , Ortega, RAO , Vaishampayan, PAV , Berg, GB , Venkateswaran, KJV



Controlled built environments like intensive care units, operating theaters and especially clean rooms are assumed to require microbial-free environments due to their human health perspective or clean industrial product assembly. However, an excessive removal and eradication of mainly beneficial microbes from the indoor environment could have adverse effects and are not sufficiently examined at all.

Our studies focused on differences in the viable microbiome of highly controlled clean rooms, moderate controlled intensive care units and uncontrolled natural indoor environments of homes and buildings in a wildlife park and a greenhouse to estimate influences of plants, animals, and their overall maintenance on indoor microbial communities. Deep sequencing technologies were applied in combination with viability assays using ATP (adenosine triphosphate) and PMA (propidium monoazide) to identify potential viable microbiomes and were supported by qPCR to investigate microbial abundance.

Different room maintenance reflected itself by characteristic microbiome compositions, which were influenced not only by the human, but also the plant microbiome. Occurrence of certain viable key species and their ecological key functions in controlled as well as uncontrolled built environments should help to develop strategies to control indoor environments in a beneficial biotechnological and much more sophisticated way for our health inside buildings.

[Paper ID420](#)

INDOOR ENVIRONMENTAL QUALITY AND WORKERS' PRODUCTIVITY IN ELECTRICITY-SAVING OFFICES –THROUGH THE EXPERIENCE OF THE GREAT EAST JAPAN EARTHQUAKE IN 2011–

Electricity-saving office; Indoor environment; Productivity

Tsushima, S.T.,

Owing to the enormous damage caused by the Great East Japan Earthquake of 2011, electricity-saving measures are promoted in offices today for both environmental and safety reasons. This paper aims to reveal how much indoor environmental quality (IEQ) has changed, and the extent to which this change impacted subjective evaluations of IEQ and productivity. The authors have conducted continuous fieldwork and questionnaire surveys in seven electricity-saving office buildings in the summers of 2011–2013. The results show that excessive indoor air temperature, such as 28°C, was avoided; however, indoor air quality did not change significantly. On the other hand, desk-level illuminance greatly decreased, from 750lux to around 400lux, after the earthquake. Moreover, the average change rate for self-estimated productivity improved from -6.6% during the earthquake year to almost 0% after the earthquake. People learned to implement electricity-saving measures in a proper way that did not spoil workers' comfort and productivity. Furthermore, we calculated the importance of each of the environmental satisfaction metrics for the integration of environmental satisfaction by using post-earthquake data. The result shows that thermal environment and indoor air quality should be improved preferentially. We need to create energy-friendly and worker-friendly office environments based on these results.



[Paper ID422](#)

LONGITUDINAL STUDY OF HOUSING FOR THE PROMOTION OF HEALTH AND WELL-BEING — ANALYSIS OF THE CAUSAL RELATIONSHIP BETWEEN LIVING ENVIRONMENT AND HEALTH—

Covariance Structure Analysis; Health Promotion; Living Environment

NAGASAWA, N. , Tanabe, ST , Kato, KR ,

With an aging population and changing social structure, health promotion has become an important factor in the daily lives of Japanese people. The objective of this study is to reveal the importance of considering the non-energy benefits within the living environment. In recent years, the correlation between living environment and health has been noted; however, the causal relationship is still unclear. The purpose of this paper is to demonstrate via longitudinal analysis that a causal relationship exists between satisfaction of the living environment, stress-related health, and low back pain.

In this study, we reported on a longitudinal analysis of living environment, stress-related health, and chronic pain in 2011 and 2013 in Japan.

We chose the three latent variables 'satisfaction of the living environment,' 'stress and fatigue,' and 'chronic low back pain' from the cross-sectional model (Fig.1), and analyzed the longitudinal data using the cross-lagged effect model and the synchronous effects model, showing the causal relationships among them.

It was revealed that 'satisfaction of the living environment' influences levels of 'stress and fatigue,' which, in turn, affects 'chronic low back pain.'

[Paper ID423](#)

RESULTS FROM OBJECTIVE AND SUBJECTIVE MEASUREMENTS OF INDOOR ENVIRONMENTAL QUALITY IN FIVE SINGLE-FAMILY HOUSES OCCUPIED BY FAMILIES: DAYLIGHT, THERMAL COMFORT, INDOOR AIR QUALITY AND SUBJECTIVE HEALTH

Dwellings; Indoor Environmental Quality; Post Occupancy Evaluation

Foldbjerg, P. , Asmussen, T F , Plesner, C , Christoffersen, J

This paper describes Post Occupancy Evaluation survey and physical measurements of five families living for one year or longer in five houses located in Germany, Austria, France and UK and are part of the Model Home 2020 project. The houses are built according to Active House principles and focus on high performance in indoor environmental quality, energy performance and environmental impact. The survey is carried out seasonally during the test year the family lives in the house to capture seasonal variations. Physical measurements were made in all main rooms of the houses. The houses have high daylight levels which is highly appreciated by the families. High daylight levels increase the risk of overheating, but this has been avoided as the families do not report overheating, and as the houses in general achieve category 1 for the summer situation according to the Active House specification. The families also indicate high satisfaction with the general indoor environment and the indoor air quality, better health, fewer sick days and improved sleep quality, that their expectations often are fulfilled, and that house automation is acceptable. The physical measurements support the importance of building automation in order to achieve good performance.

[Paper ID424](#)

NONSPECIFIC BUILDING-RELATED SYMPTOMS OF OFFICE EMPLOYEES AND INDOOR AIR QUALITY OF THE WORK ENVIRONMENT: A SURVEILLANCE STUDY FOR THEIR RELEVANCE IN OFFICE BUILDINGS IN JAPAN



building-related symptoms; temperature and humidity; volatile organic compounds

Azuma, K. , Ikeda, KI , Kagi, NK , Yanagi, UY , Osawa, HO ,

We conducted a cross-sectional study to examine the association between indoor air quality and nonspecific building-related symptoms of employees working in office buildings. The surveys were conducted from January 2013 to September 2013 in 11 offices with 107 employees during winter and in 13 offices with 207 employees during summer. Multivariate analyses revealed that during winter, general, upper respiratory, and skin symptoms were significantly associated with increased suspended particles (particle size [p.s.] > 5 µm), increased aldehydes or volatile organic compounds, and lower room temperature. In addition, skin symptoms were associated with lower humidity. During summer, upper respiratory and skin symptoms were associated with increased toluene and lower room temperature.

[Paper ID425](#)

IN-SITU MEASUREMENTS OF VOLATILE ORGANIC COMPOUND SORPTION COEFFICIENTS ON BUILDING MATERIALS: FIRST FIELD CAMPAIGN IN A LOW ENERGY BUILDING.

Field campaign; Sorption parameters; Volatile Organic Compounds

RIZK, M.R. ,

A transportable device based on the coupling of a Field and Laboratory Emission Cell (FLEC) and a Proton Transfer Reaction - Mass Spectrometer (PTR-MS) has been used for the first time to perform in-situ measurements of sorption parameters. The measurements were carried out during an intensive field campaign conducted in a low energy French school. Sorption coefficients of 14 volatile organic compounds were successfully measured for 10 different surfaces within a few hours for each surface (<12 hours/surface). The measurements indicate that sorption parameters can be significantly different between surfaces and stress out the need for in-situ measurements of sorption parameters. These results can be useful as inputs for new indoor air quality models, whose purpose is to predict indoor concentrations of VOCs.

[Paper ID426](#)

MONITORING AND AUDITING OF INDOOR AIR QUALITY IN EUROPEAN BUILDINGS: STATUS AND PERSPECTIVES

Audit; Indoor air quality; Indoor air quality management

Fernandes, E. , Madureira, J , Barrero-Moreno, J , Geiss, O , Kephelopoulou, S ,



In the context of the EC's initiatives on IAQ attention has been paid on the development of harmonization methods and tools to reliably assess exposure to indoor air pollutants in various buildings typologies and to tackle the emissions source control issue in the EU MS. These methods and tools are to play a key role in both assessing the indoor air status conditions and managing health risks in energy efficiency buildings in the EU. The INDOOR AIR MONIT project developed a framework of harmonised criteria, protocols and monitoring techniques for indoor air pollutants to cope with five different IAQ objectives: 1) guideline compliance; 2) health and comfort complaints; 3) remediation efficiency; 4) source attribution of indoor air pollution and 5) population exposure survey. Each of these IAQ objectives has its own specific scope, targets and associated operational practices. AIRLOG introduced a sixth dimension to put emphasis and cope with the necessity of integrating IAQ measurements and modelling. This includes appropriate consideration of the type and strength of indoor air sources and, ultimately, the ventilation level, since the early design phase of a building. HEALTHVENT project presented a strategy which coupled source control with health-based ventilation requirements.

[Paper ID427](#)

VENTILATION EFFECTIVENESS AND CONTAMINANT DISTRIBUTION IN AN OCCUPIED SPACE CONDITIONED WITH LOW EXERGY VENTILATION TECHNOLOGIES IN THE TROPICS

decentralized dedicated outdoor air system; low exergy; ventilation effectiveness

Mahmoudi Saber, EMS. , Mast, MM , Tham, KWT , Leibundgut, HL

Low exergy concept can be implemented in air conditioning system of the tropical buildings through a reduction of the difference between operational temperature of cooling system and indoor space whilst meeting thermal comfort requirements. Decentralized dedicated outdoor air system (DDOAS) coupled with radiant cooling system (RCS) are low exergy designs which can potentially reduce exergy destruction in cooling system of buildings while providing adequate air quality for occupants. In this study, ventilation effectiveness of a DDOAS-RCS design with floor supply – ceiling exhaust (FS-CE) and radiant ceiling panel has been investigated in an experimental setup located in Singapore. Air change efficiency (ACE) and contaminant removal effectiveness (CRE) of the designed system have been determined using tracer gas step down test under various ventilation rates. The results showed that ACE of DDOAS-RCS design with FS-CE distribution is close to that of mixing strategy and there is no significant difference for five considered ventilation rates in the range of 0.44-0.92 lit/s/m². It was also found that each change in occupancy for the space with 70 m³ volume at ventilation rate of 0.62 lit/s/m²; takes about two hours to reach a steady state CO₂ concentration and this change happens gradually throughout the space.

[Paper ID428](#)

ASSESSING VENTILATION RATES OF PORTUGUESE FLATS UNDER DIFFERENT BOUNDARY CONDITIONS

Air change rate; Tracer gas; Ventilation

Almeida, R.M.S.F.. , Barreira, E. , Freitas, V. ,



Indoor air quality is crucial for occupants' health and wellbeing. In mild climates, natural ventilation (sometimes mixed) is the most common method to provide the required fresh air. However, in Portugal, commonly no specific inlet ventilation devices are used in construction and, therefore, ventilation success is strongly dependent on buildings' airtightness and user behaviour.

This paper reports the results of a field campaign where ventilation rates were measured in four typical Portuguese flats, each built on a different decade. Several set-ups were prepared in each flat, allowing for a complete characterization of their performance. Measurements were carried out separately in each room and with different boundary conditions (door open/closed, mechanical extraction on/off). The tracer gas method (decay technique) was used and 44 tests were made.

Results are discussed. The standard target value was never achieved in the main compartments and an attempt to correlate ventilation rates with glazed area is made.

ASSESSING THERMAL COMFORT IN PORTUGUESE EDUCATIONAL BUILDINGS: MEASUREMENT VS. PUPIL PERCEPTION

Educational building; Metabolic rate; Thermal comfort

[Paper ID](#)

Almeida, R.M.S.F., Ramos, N., Freitas, V.,

In modern societies, educational buildings play a key role in creating a good social climate and conditions in which children and young people can develop. Several international studies have been conducted to evaluate students' performance and the factors that most influence it, including classrooms' thermal comfort. Yet, various revealed differences between pupils' perception and the results of thermal comfort models.

This paper reports the results of a field campaign to assess thermal comfort conditions in Portuguese educational buildings, including classrooms and libraries. Global comfort was assessed by PMV index and according to EN 15251 adaptive model. In parallel, pupils' perception was collected through specific questionnaires adapted according to their ages. Answers allowed a detailed analysis regarding the definition of the best methodology to quantify the adequate children's metabolic rate to be considered in the thermal comfort numerical analysis.

It was found that when using PMV analytical approach, metabolic rate must be adjusted. Generally, students felt comfortable and a large majority would maintain the indoor conditions unchanged. No perfect agreement was found between calculated PMV and the mean thermal sensation collected through questionnaires. Moreover, when comparing PMV index and EN 15251 model, PMV stands out as more restrictive.

[Paper ID430](#)

VOLATILE ORGANIC COMPOUNDS DURING AND AFTER THE CONSTRUCTION IN NEW BUILT SINGLE-FAMILY HOUSE

Building materials; VOC;

Hyttinen, M.,



Concentrations of volatile organic compounds (VOCs) and ventilation rates were measured in new built detached house. The house was built according to building code's demands for energy efficiency and air tightness. Ventilation was shut down during the construction to avoid contamination of the ventilation system. VOC concentrations were high level during and immediately after the finishing of the house (total VOCs over 5000 $\mu\text{g}/\text{m}^3$). VOCs were mainly emitted from the wood based materials (terpenes), sealants and water based paints (oximes and alcohols). Some of the identified compounds (e.g. 2-propanone oxime, 2-butanone oxime) found are strong sensory irritants. Concentrations of VOCs were at high level for several weeks after the inhabitants moved in the new house. Especially concentrations of terpenes (mainly alpha-pinene and delta-carene) stayed a high level. Concentrations of oximes decreased in several days after the finishing of the house. The results revealed that harmful VOCs are present in brand new houses indicating that efficient ventilation should be used already before the inhabitants have moved in.

[Paper ID431](#)

GAS-SENSORS NETWORKS: RELEVANT TOOLS FOR REAL-TIME INDOOR AIR QUALITY INDICATORS IN LOW ENERGY BUILDINGS

Chemicals Sensors; IAQ; VOCs

Caron, AC. , HANOUNE, BH , REDON, NR , CODDEVILLE, PC

Due to their potential, electronic gas sensors networks, especially those based on metal oxide semi-conducting materials, are currently the subject of active research for many applications, including air pollution. Indoor air quality (IAQ) receives an increasing attention because of long-term occupancy of confined environments with high specific pollutants concentrations. The present study focuses on monitoring IAQ using multi-sensors networks. Five multi-sensors systems, containing each six commercial semi-conductor gas sensors especially selected to detect the widest gas species usually present in indoor atmospheres, were installed in a 140 m³ classroom of a Low Energy Junior High School in North of France, together with conventional and advanced analytical techniques, during an intensive measurement campaign.

The semiconductor sensors monitor the increase of indoor pollutants when the ventilation system is off, and a very efficient decrease of the chemical compounds concentrations, together with the intake of outdoor pollutants, when the ventilation is active. The results from these devices present a good correlation with the results from standard gas analyzers.

[Paper ID433](#)

PARTICULATE MATTER SIZE DISTRIBUTION MEASUREMENTS AND ESTIMATION OF THE PARTICLE DEPOSITION IN THE LUNG OF PEOPLE WORKING IN MODERN OFFICES IN ATHENS – OFFICAIR PROJECT

lung deposition; modern offices; particulate matter

Sakellaris, I. , Saraga, D. E. , Pilou, M. , Kalimeri, K. K. , Housiadass, C. , Bartzis, J. G.



Exposure of office occupants to compounds emitted from potential sources in modern offices can be quite substantial and might significantly affect human health. Especially exposure to particulate matter (PM) has been associated with cardiopulmonary diseases, respiratory tract infections and cancer. This study presents part of the results obtained during the OFFICAIR project's campaign, which took place in five modern office buildings in Athens, Greece. The collected data were used in a 1D mechanistic dosimetry model in order to calculate particle deposition along the human respiratory tract (HRT) during exposure to indoor aerosol sources. Results showed that office occupants' exposure is higher in ultrafine particles, which contribute the biggest percentage of the 8h daily dose.

[Paper ID434](#)

ORGANIC COMPOUNDS IN RESIDENTIAL BUILDINGS

indoor environment; organic compounds;

Meciarova, L. M., Vilcekova, S.V., Budaiova, Z.B.,

Currently, people deal mainly with comfort, design and energy saving in connection with their housing. Considering that people need 6-10 l of air per minute depending on the activity, more attention should be given to indoor air quality, which directly affects their health, performance and well-being. The selection of appropriate building materials is one of the ways to reduce the concentration of VOCs in the indoor air. The aim of this study was to determine the contribution of building materials to TVOC concentrations in the indoor environment of two apartments in Slovakia and analysis of individual VOCs using relatively new portable device that combines gas chromatography with surface acoustic wave detector. The results showed that the use of low-emission paints is advantageous and bonding primer is important source of VOC emissions. It follows that; in the selection of wet building materials we must pay attention not only to paints but also to other layers of structure. Analysis of VOCs with zNose® confirmed the presence of only one identical compound – toluene – in apartments.

[Paper ID435](#)

FIELD STUDIES ON THE EFFECT OF THE INDOOR THERMAL ENVIRONMENT ON SLEEP IN SUMMER AND WINTER

Field study; Indoor thermal environment; Sleep

Ohashi, C., Ikaga, T., Ando, S., Umishio, W., Takayama, N., Yanagisawa, M

Sleep problems can have profound economic and health effects. Recently, the effect of the indoor thermal environment on sleep has attracted attention. However, the relationship between the indoor thermal environment and sleep, by season, has not been fully studied. Accordingly, the purpose of this study was to elucidate the effect of the indoor thermal environment on sleep in both summer and winter. Field studies comprising actual measurements and questionnaire surveys were conducted during summer 2013 and winter 2014. Statistical analysis of the data yielded the following main results. First, sleep efficiency, defined as the ratio of total sleep time to total time in bed, was highest at a bedroom temperature of 27.6 °C in summer and 13.0 °C in winter. Second, after controlling for personal attributes, sleep efficiency decreased by 3.2% per 1 °C increase in bedroom temperature over 27.6 °C in summer, and by 0.3% per 1 °C below 13.0 °C in winter.



[Paper ID436](#)

IMPROVING THE INDOOR AIR QUALITY BY EFFICIENT EXPOSURE REDUCTION: THE SURFACE EMISSIONS TRAP

Building dampness; Indoor air purification; Volatile organic compounds

Larsson, P. , Markowicz, L , Mattsson, W ,

The surface emissions trap (cTrap), a new device for reducing emissions of volatile organic compounds and particulate matter from surfaces while allowing evaporation of moisture, was used to improve the indoor air quality of a school building with elevated air concentrations of 2-ethyl-1-hexanol. A clear improvement of the perceived air quality was noticed a few days after a cTrap prototype had been attached on the PVC flooring. In parallel, decreased air concentrations of 2-ethyl-1-hexanol were found as well as a linear increase of the amounts of the same compound adsorbed on the installed cTrap cloth as observed up to 13 months after installation. This study suggests that a surface emissions trap may represent a fast and efficient means of restoring the indoor air quality in a building e.g. after water damage leading to irritating and potentially harmful emissions from building material surfaces indoors.

[Paper ID437](#)

MEASUREMENTS OF BLOOD FLOW AND BLOOD PRESSURE UNDER DIFFERENT INDOOR TEMPERATURE AND BODY POSTURAL CONDITIONS, AND DEVELOPMENT OF A NEW HUMAN SIMULATION MODEL

Blood flow; Blood pressure; Subjective experiment

Sakamoto, H. , Chiba, Y , Hayase, T , Funamoto, K , Saijo, Y , Goto, T

Numerical simulation with human thermophysiological model is one of the useful methods in order to evaluate the health risks caused by severe thermal environments. In addition, sudden changes in blood pressure (BP) and inadequate blood flow are key factors of those health problems. Therefore, we are developing a new human thermophysiological model, which can predict BP and blood flow as well as body temperature. In this study, we measured human physiological responses including BP and blood flow, because little experimental data on BP and blood flow were available to be referred. The measurements were carried on a healthy young man under three different conditions; 28°C Sedentary, 35°C Sedentary and 28°C Standing. The BP was measured with the oscillometric method, and the blood flow was measured with an ultrasound imaging equipment and a laser blood flow meter. In these measurements, we observed the quantitative changes in blood flow, BP, stroke volume and heart rate due to indoor temperature and body position. On the other hand, we developed a simulation model of the cardiovascular system to be integrated into the new human model. The simulation results by this model were found to be reasonably matched with the measurements.

[Paper ID438](#)

VENTILATION EFFECTIVENESS COMPARISON BETWEEN EXTRACT VENTILATION AND BALANCED VENTILATION IN A SCALE MODEL

balanced ventilation; extract ventilation; ventilation effectiveness

Cremers, BE. ,



The differences between extract ventilation and balanced ventilation are subject of many discussions in sales markets where both solutions have their share. Often, the differences are marked in terms of energy, because balanced ventilation is normally accompanied by heat recovery. But there is another difference in terms of the ventilation effectiveness of the system. This document reports experiments in a scale model of a house showing the difference between extract ventilation and balanced ventilation in ventilation effectiveness, and therefore in achievable indoor air quality. The ventilation effectiveness is measured in terms of the cleaning time, i.e. the time it takes for smoke to be completely extracted from individual rooms. The results indicate that for an undisturbed (design) system the cleaning time for individual rooms is independent on the ventilation system. But in disturbed situations like an open window or wind pressure on the building, the cleaning time is different for various individual rooms, and dependent on the ventilation system. The conclusion is that for balanced ventilation, the ventilation effectiveness is not reduced by occupant behavior or wind conditions. On the other hand, for extract ventilation the ventilation effectiveness is lower in particular individual rooms as a result of these disturbances.

[Paper ID439](#)

CO2 CONCENTRATIONS MEASURED IN 400 CLASSROOMS OF ELEMENTARY/SECONDARY SCHOOLS IN TOKYO

Administrative data; Evidence based approach; IAQ

Iguchi, K.I. ,

In this study, the administrative data on school environmental hygienic audit were used as the evidence. The air quality during winter period in elementary/secondary schools located in metropolitan district X was analyzed by using results of the environmental hygienic audit. The period of analysis was set as 3 years from 2007 to 2009. The following conclusions were obtained;

- 1) The average values of air temperature, the relative humidity, and CO2 concentration in classrooms of the elementary schools met the standard of school environmental hygiene. On the other hand, the average CO2 concentration of the secondary schools exceeded the standard values of 1500 ppm.
- 2) The clear tendency that the lower the outdoor temperature, the higher the heating usage ratio, was observed both in the elementary and the secondary schools. Under the same outdoor temperature condition, the heating usage ratio in the secondary schools was higher than that in the elementary schools.
- 3) Under the same outdoor temperature condition, the average room temperature in the classrooms of the secondary schools was significantly higher than that of the elementary schools. The average CO2 concentrations in the secondary schools exceeded the standard values under the all temperature classes.

[Paper ID440](#)

INFLUENCE OF OUTDOOR TEMPERATURE ON THE ACCIDENTAL RISK IN ELEMENTARY SCHOOLS CONSIDERED WITH SATURATION LEVEL OF AIR CONDITIONERS INTO CLASSROOMS IN TOKYO



Accidents in schools; Air conditioner; Risk of accidents

Nakajima, H.N. , Iwashita, G.I.

The data of accidents in the elementary schools in the ward areas and the urban districts of Tokyo were investigated with considering the rate of air conditioners being placed in classrooms. The rate of air conditioners being placed in classrooms in the ward areas of Tokyo was four times higher than that in the urban districts of Tokyo. The data of accidents of the elementary schools were obtained from the NAASH (National Agency for the Advancement of Sports and Health), and the period of analysis was set as 3 years from 2005 to 2007. While the occurrence rate of accidents in classrooms in the ward areas during summer period was decreased with the years from 2005 to 2007, that in the urban districts was constant with the years. It was found that the difference in the rate of air conditioners being placed in classrooms might have an effect on the occurrence rate of accidents in the classrooms. The decrease in the occurrence rate in classrooms of elementary schools during summer period may be attributed to improvement in students' concentration provided by air conditioners especially during the class accompanied with operation works, e.g., comprehensive learning, drawing and crafts, and classroom activities.

[Paper ID442](#)

COUPLED THERMODYNAMIC AND BIOLOGIC MODELING OF LEGIONELLA PNEUMOPHILA PROLIFERATION IN DOMESTIC HOT WATER SYSTEMS

Domestic Hot Water systems; Legionella Pneumophila; Thermodynamics and Biology

Van Kenhove, EVK. , Janssens, AJ , Laverge, JL , De Vlieger, PDV

The production of Domestic Hot Water (DHW) dominates the total energy demand. One of the main reasons for the high energy demand is that DHW is stored and distributed at temperatures above 55°C to mitigate the risk of infecting the DHW system with "Legionella Pneumophila". At these temperatures, "Legionell" bacteria are effectively killed. For most of the applications of DHW, temperatures of only 30-40°C are required. This disparity (between 55 and 30-40°C) doubles the temperature difference between the DHW system and the environment and has a detrimental effect on the efficiency of DHW production units.

A simulation model will be developed that allows to investigate the infection risk for "Legionella" in the design phase of a DHW system and to test the effectiveness of disinfection techniques on an infected system. In addition to the modeling work, a test rig will be built and the relevant temperature and use profiles will be measured in DHW systems of several buildings. With the thermodynamically validated model, "Legionella" infection risk of 5 to 10 DHW system configurations will be assessed and new design guidelines will be proposed based on an optimization study that looks for the trade-off between infection risk and energy efficiency.

[Paper ID444](#)

THE INFLUENCE OF LED LIGHTING ON THERMAL COMFORT, HEALTH AND ENERGY

LED Light; Thermal comfort; Thermoregulation

Kulve, M.. , Schellen, L. , Frijns, A.J.H. , Schlangen, L.J.M. , Marken Lichtenbelt, W. van,



Light is an important factor in creating a comfortable and pleasant environment. This does not solely depend on visual information, but also on non-visual effects of light like its influence on alertness, mood, sleep-wake rhythm and wellbeing. It is likely that light also plays a role in thermoregulation and may affect thermal comfort. However, the relation and interaction between light, thermoregulation and thermal comfort is not fully known. The main objective is to investigate the relation between light, thermoregulation and thermal comfort. Therefore, the effects of bright and dim light on thermoregulation, human energy expenditure, thermal comfort and alertness will be studied. Furthermore, we will explore how this knowledge can contribute to comfortable and healthy buildings.

[Paper_ID446](#)

ON-LINE MONITORING OF VOLATILE ORGANIC COMPOUNDS IN A LOW ENERGY BUILDING: THE ROLES OF MATERIAL EMISSIONS, OUTDOOR SOURCES AND VENTILATION.

Auto-TD-GC-FID; Real-time measurements; VOC

Verriele, MV. , Leonardis, TL , Dusanter, SD , Schoemaecker, CS , Locoge, NL ,

While typical averaged pollutant levels for standard residential buildings are well reported in the literature, there is still a lack of time resolved concentration data, especially for energy-efficient buildings. The goal of the MERMAID program is to investigate Indoor Air Quality (IAQ) in newly-built low energy public schools through a joint experimental and modeling approach. Real time profiles of VOCs, NO_x, ozone and HO_x (OH and HO₂) have been monitored indoor and outdoor during an intensive campaign using a large panel of instruments. 61 VOCs of 2 to 12 atoms of carbons have been measured hourly by TD-GC-MS/FID ; Three clusters of species were identified as a result of correlation and factorial analyses (PCA) on this indoor data set. The two first groups of variables clearly gather VOCs from outdoor sources: e.g. light alkanes (ethane, propane ...), alkylpentanes, light alkenes, benzene and ethylbenzene ; whereas a third set of variables groups together an exhaustive list of species for which emission factors higher than 1µg.m⁻².h⁻¹ have been measured from at least one surface (toluene, octane, pinenes ...). The concentration profile for these species is clearly indexed on the ventilation operating modes whereas other species are influenced by outdoor inputs.

[Paper_ID447](#)

SENSORY EVALUATION OF THE ODOUR RETAINING EFFECT OF SEALANT ON HEAT-TREATED WOOD

Odour retention; Sealant; Sensory evaluation

Klinke, HBK. , Lund, BWGL winther, Venås, THV mark, Lindegaard, BKV , Dahl, pd , Sørensen, THS



The objective of this study was to evaluate the ability of sealant to block odours from heat-treated wood (HTW). An untrained panel of at least twenty persons performed evaluation of the odour from HTW with and without sealant and from the sealant on glass. The odour from heat-treated wood was unacceptable with strong intensity. The odour from sealant was clearly acceptable with no/weak intensity. The sealant was able to seal the emissions of odour from heat-treated wood with the same sensory evaluation result after 7 and 28 days: Just acceptable and moderate intensity. The volatile substances emitting from HTW and HTW with sealant were sampled after 28 days at the outlet funnel used for odour evaluation. The main substances were acetic acid, 2-furaldehyde (furfural), 5-methyl-2-furaldehyde (methylfurfural) and acrolein (2-propenal). The total concentrations of VOCs and carbonyls were significantly reduced by 86 %, when sealant was applied to the HTW.

[Paper ID448](#)

FULL-SCALE ASSESSMENT OF THE PERFORMANCE OF AN ASPIRATION EFFICIENCY BASED POLLUTION CONTROL DEVICE FOR BUILDING HVAC SYSTEMS.

Energy Consumption; HVAC Systems; Particulate Matter

McNabola, A. , Morgan, D.

The control of particulate air pollution using the concept of aspiration efficiency has recently been estimated to have the potential to reduce energy consumption in building HVAC systems by 15-20%. Such a system could offer considerable savings and environmental benefits providing healthier buildings for the atmosphere. However previous investigations which developed this aspiration efficiency reducer (AER) have done so using a scale model, while a number of assumptions in the estimation of energy performance we also made. This investigation comprises a full-scale performance assessment of the AER.

Two identical air handling units were constructed and installed side-by-side on the roof of a commercial building. One of the air handling units provided a control while the other was fitted with the AER and the energy performance and pollution control capabilities of both were assessed. Pressure drop across the filters and outdoor and in-duct particle concentration in both air handlers were compared.

The results of this investigation confirmed that the addition of an AER on to the inlet of a HVAC system reduces energy consumption over the lifetime of a typical filter. Considerable scope exists to the optimisation and refinement of the AER for differing HVAC settings and differing environmental settings.

[Paper ID449](#)

INVESTIGATING THE EFFECT OF TOTAL THERMAL ENVIRONMENT AND ITS VARIATION ON SLEEP

Air Turbulence; Sleep; Total Thermal Environment

Miyake, EM. , Unno, KU , Tsuzuki, HT , Tanabe, ST



The purpose of this study was to investigate the effect of total thermal environment and its variation on sleep. Sleep is crucial for human health, and lack of sleep impacts mental performance. Of the many factors affecting sleep, thermal environment is known to play an important role, and its effect on sleep has been an active area of research for a long time. However, most studies only consider an average value of thermal environment during the night. We carried out a field survey in September and October 2013 in actual bedrooms at 16 residences. Thermal environment was monitored continuously during the subjects' sleep sessions for 5 consecutive nights. All subjects wore an actigraph unit to monitor sleep and questionnaires were filled in before and after sleep. The results showed that an increase in air turbulence increases the probability of awakening, suggesting that variation in air velocity may cause sleep disruption. To take into account all factors of thermal environment, thermal load on body and its variation were calculated and their effects on sleep were evaluated. From these results, it was concluded that local heat stimulation and draft might be the cause of sleep disruption.

[Paper ID450](#)

EVALUATION OF SIMULTANEOUS CONTROL OF WINDOW SYSTEM AND AIR-CONDITIONER IN SMART HOUSE

Energy Saving; HEMS; Simultaneous Control

Ebe, ME. ,

In the recent years, in Japan, building materials of window system which are controllable windows and blinds are being used widely, and many building materials begin to be used in houses. For that reason, usefulness of having to estimate the effects of energy load reduction of residential thermal environment control through the use of HEMS, air conditioner and controllable building materials, which are suitable for residential environmental conditions, is considered to be high. In this study, the power consumption of simultaneous control of natural ventilation window, solar radiation shielding blinds, insulating blinds and air-conditioner and one of single control of air-conditioner were compared. Then, the effectiveness of simultaneous control was verified.

A simulation program was developed using MATLAB. First, by comparing indoor temperature measured in the object building with one calculated using the simulation of this control system, the validity of indoor temperature change calculation model is shown. Second, by using this model, simulation was performed under 2 conditions; conditions of different insulation material performances, and conditions of different comfortable levels of residents. In all conditions, power consumption of simultaneous control reduced the most comparing with that of single control.

In conclusion, the effectiveness of collaboration control system was shown.

[Paper ID451](#)

EFFECTS OF AN INDOOR THERMAL ENVIRONMENT CREATED BY HEATING SYSTEMS IN JAPAN BASED ON SKIN MOISTURE CONTENT AND THERMAL COMFORT

Heating System; Skin Moisture Content; Subjective Experiment

Sakurai, Y.S. , Tanabe, S. , Hirose, A , Shinohara, MS , Matsumae, KM , Murakami, RM



Recently, there has been increasing concern about dry skin in Japan with regards to beauty and atopic dermatitis. People are likely to feel dry more frequently in a heated room in winter. The purpose of this study was to determine the effects of a thermal environment created by heating systems on skin moisture content and thermal comfort and to propose an effective method to maintain skin moisture content when using heating systems.

In this study, subjective tests were conducted in model living rooms in a climate chamber. The tests were conducted in a total of 18 different thermal conditions. Air temperatures were controlled using a floor heating system or an air conditioner, and relative humidity conditions were set using a humidifier. During the tests, the subjects answered questionnaires regarding thermal comfort.

The results suggest that the air velocity in an air-conditioned room increases with increasing air temperature, resulting in dry skin on the face. Therefore, it is reasonable to suppose that avoiding direct exposure to airflow is effective for increasing skin moisture content.

The results also suggest that skin moisture content is influenced by relative humidity, absolute humidity, and air temperature.

[Paper ID452](#)

EFFECT OF PARTITIONING FURNITURE SIZE ON AIRBORNE INFECTION RISK IN MULTI-BED WARD

Infection control; Multi-bed ward; Partition

Suzuki, M.S. ,

The objective of this study was to examine the relationship between the size of the partitioning furniture separating patients in a multi-bed ward and the airborne infection risk to those patients. Computational fluid dynamics analysis was used to analyze the airborne infection risk. A four-bed ward, in which one patient was infected with an airborne disease, was simulated, with tracer gas being used to simulate the spread of the airborne pathogens. Each patient's airborne infection risk was simulated with two types of ventilation layout and six variations of partitioning furniture. When no partitioning furniture was used, the airborne infection risk to the patient in the bed next to the infected patient was the highest. With partitioning furniture installed between the beds, however, the airborne infection risk to that patient was significantly reduced. However, the airborne infection risk to the patient in front of the infected patient increased as a result of installing the partitioning furniture. In addition, depending on the size of the partitioning furniture, its installation negatively affected the airflow characteristics and exhaust efficiency. This tendency was particularly noticeable with partitioning furniture that was 2200 mm in length.

[Paper ID453](#)

POLLUTION PREDICTION FOR A GROUP OF PLANNING HOSPITAL BUILDINGS BY CFD

CFD simulation; Hospital buildings; Pollutant dispersion

Qiu, J.Y. , He, Q.B. , Liu, Y.H. ,



As public places that serve vulnerable populations, hospital buildings should be designed with consideration of potential pollution sources and their dispersion characteristics. In this study we establish a three-dimensional model of a group of planning hospital buildings to predict the pollutant dispersion of surrounding traffic vehicles, respiratory clinic and medical garbage truck with computational fluid dynamics (CFD) simulation. The three different sources are simulated respectively. The results show that influenced by atmospheric flow, the respiratory clinic source and medical garbage truck source will probably pollute the local environment and do harm to the inpatients, while surrounding traffic vehicles will not affect the hospital buildings. In summer case, whirling flow will generate north outside the respiratory clinic building and result in lingering contamination, which calls for building structure adjustment. In both summer and winter cases, medical garbage truck will bring severe pollution which will last for a comparatively long time, but the pollutant will not directly affect the air near the buildings and supposed to be reduced if shrubs would be planted on both sides of the logistic road.

[Paper ID454](#)

FULL SCALE TEST OF OFFICE ROOM WITH SUSPENDED CHILLED BEAM INTEGRATED WITH RADIANT PANEL IN HEATING MODE

chilled beam; radiant panel; thermal comfort

Mustakallio, PM. , Korinkova, AK , Kosonen, RK ,

One attractive solution especially in the office buildings is to integrate prefabricated radiant panel into chilled beams for heating. This would save the floor space and would simplify installation process. In this paper thermal conditions in the office room with chilled beam integrated radiant panel were analyzed by the full-scale laboratory test. The office room was measured in six steady-state heating cases. Indoor climate conditions in all cases were at good level, and even reasonable in the case where window temperature was nearly 10 degC. Radiant asymmetry and vertical temperature stratification in all cases was below maximum values for category ISO-7730 A conditions. The highest room air velocities and draught rate readings were at reasonable level, 0.16 m/s and 17%. Chilled beam integrated with radiant panel can well replace the radiator system in most office buildings. The indoor climate conditions in all cases were good, still the most advantageous situation would be to ensure that design window surface temperature is at least 14 degC. It would give good thermal conditions in the occupied zone and also small vertical temperature stratification in the whole room.

[Paper ID455](#)

'MONITORING AND MODELLING EMERGING INDOOR AIR POLLUTANTS'

modelling indoor air pollution; ozone removal; secondary indoor air pollutants

Kruza, M. , Carlaw, N , Lewis, A ,



Since the 1970s, increasing attention has been paid to indoor air quality, led in part by the emergence of building related symptoms such as headaches, allergy and eye irritation. Indoor air pollutants are generated through activities such as cooking, cleaning or smoking, as well as emitted from building materials, paints, carpets, furnishing and cleaning products. They can also ingress from outdoors, and consequently, indoor environments often contain higher concentrations of air pollutants than outdoors.

There is increasing evidence that indoor secondary air pollutants may be responsible for some of the observed health effects indoors. Further, such secondary pollutants are formed through secondary chemistry or surface interactions.

The goal of this study is to quantify ozone deposition on different indoor surfaces and the potential production of secondary pollutants through this process.

[Paper ID456](#)

INCORPORATING OCCUPANT'S THERMAL COMFORT INTO SIMULATIONS OF INDOOR AIR POLLUTANT TRANSFER THROUGHOUT THE RESIDENTIAL ENVIRONMENT.

Indoor air quality,; Occupants' behaviour,; Thermal comfort

McGrath, J A. , Byrne, M A

The current work focuses on incorporating an algorithm for controlling the opening/closing of internal doors based on occupant's thermal comfort. This provides a dynamic representation of the occupant's behaviour within the environment, while predicting a more realistic transfer of indoor air pollutants throughout the residential environment. An existing computational model, IAPPEM is modified to predict the distribution of indoor air pollutants throughout the residential environment based on windows/doors opening/closing patterns which are deduced from internal zone temperatures. Adaptive algorithms are incorporated to analyse the interaction between the occupants and the buildings to provide a better understanding of the distribution of air pollutants throughout the residential environment. This allows the capability of assessing the effects that temperature and occupant behaviour have on changes in ventilation rates, and subsequently their airborne pollutant exposure. The results demonstrate considerable variation in both living room and bedroom concentrations using a varying door opening pattern compared to open/closed doors scenarios.

[Paper ID457](#)

MICROBIAL GROWTH AND INTERACTIONS ON INDOOR SURFACES - MICROBIAL SECONDARY METABOLITES AND MYCOTOXINS

Fungal growth,; Moisture; Mycotoxin

Nielsen, KFN. , Dosen, ID , Andersen, BA ,

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[Paper ID458](#)

AIR QUALITY PERFORMANCE OF DUCTLESS PERSONALIZED VENTILATION IN CONJUNCTION WITH DISPLACEMENT VENTILATION: IMPACT OF WALKING PERSON

"Ductless" personalized ventilation; Bio-effluents; Exposure

Bolashikov, ZDB. , Lu, PL , Malinowski, TJM , Melikov, AKM



The present experiment evaluates the impact of air disturbances from a walking person on inhaled air by ductless personalized ventilation (DPV) with displacement ventilation (DV), when a seated occupant is the source of pollution: bio-effluents and exhaled air. The measurements took place in a full-scale office room with two side by side workstations. Each desk included a DPV, a personal computer and desk lamps. Two dressed, breathing thermal manikins were used as seated occupants. DV floor-standing air supply was installed at the wall facing the workstations. A real person was walking between the desks and the DV supply. Pollution from feet and exhaled air by one manikin was simulated with tracer gases. Room temperature of 26 °C and 90 L/s DV supply flow rate were kept constant. Measurements under numerous combinations of DPV operation modes and supply flow rates were performed. Tracer gas concentrations in inhaled air by the two manikins were measured. The DPV was not able to protect the exposed person from contaminants emitted from a sitting and polluting occupant when there were disturbances close to the DPV. However, using the DPV at the polluting manikin's workstation resulted in better inhaled air quality for the polluting manikin.

[Paper_ID459](#)

INVESTIGATIONS OF THERMAL TREATMENT OF LOADED HVAC FILTERS FOR COMBINED MICROBIAL INHIBITION AND VOC PARTIAL DESORPTION

Filtration; IAQ; Microbial aerosol

MORISSEAU, Kevin. , JOUBERT, AJ , ANDRES, YA , LE COQ, LLC

The aim of this study is to evaluate at laboratory scale the feasibility of in-duct air treatment implemented in individual housing composed of particle filtration and gaseous compound adsorption. Thermal treatment was investigated to reduce the microbial population in filters and to partially regenerate the adsorbent to extend the process lifetime. This paper was limited to the microbial study. HVAC fibrous in flat geometry were preloaded with micronized rice particles naturally containing "Penicillium chrysogenum". Clogging was performed at the nominal filtration velocity and was stopped at the filter mid-life. Then, microbial growth was ensured by incubating the filters at 25°C and 90% RH. Thermal treatment with different temperature (up to 85°C) and time period were performed. Finally, microbial concentration in the filters was quantified by Colony Forming Unit counting. Thermal treatment was significantly efficient for temperature of 70°C or higher and for 1 week of treatment. More significant microbial growth inhibition is expected in dynamic flow conditions, which may decrease the treatment time period. Regarding the AC filter, a partial regeneration is expected in the experimental conditions, as well as a significant lifetime increasing. Microbial inhibition and partial AC regeneration should be both possible by thermal treatment.

[Paper_ID460](#)

RESIDENTIAL VENTILATIVE COOLING IN NATIONAL ENERGY PERFORMANCE REGULATIONS: PROPERTIES AND IMPACT ON ENERGY CONSUMPTION AND OVERHEATING

energy performance regulation; overheating; ventilative cooling

Pollet, I. , Germonpré, S , Vens, A ,



Ventilative cooling as passive technique can limit overheating and decrease cooling energy consumption. The national energy performance regulations determine whether, how and under which requirements ventilative cooling can assist to reduce cooling demand and overheating. In this study a kind of sensitivity analysis is performed to assess the impact of parameter variation on the ventilative cooling effect. One reference dwelling is introduced into the EP software of Belgium, France and The Netherlands.

As can be expected, ventilative cooling always decreases the cooling demand (28 to 74% in Belgium, 29 to 35% in The Netherlands for the studied case), especially in combination with mobile solar shading. In Belgium also the risk on overheating and in France the summer indoor temperature decrease by applying ventilative cooling. In The Netherlands, the risk on overheating cannot be assessed.

The primary energy consumption is lower when ventilative cooling is applied (up to 9% in Belgium and up to 3% in The Netherlands) except for France where openable windows remarkably increase the heating demand (up to 29%). These remarkable differences urge the need for a European ventilative cooling standard to harmonize national energy regulations.

[Paper ID461](#)

PSYCHOSOCIAL WORK ENVIRONMENT AND BUILDING RELATED SYMPTOMS

Health; Offices; Quality of work life

Roda, C. R. , Bluysen, P. M. B. , Mandin, C. M. , Fossati, S. F. , Carrer, P. C. , De Kluizenaar, Y. K. , Mihucz, V. G. M. , De Oliveira Fernandes, E. , Bartzis, J. B. ,

Besides indoor environmental quality, psychosocial work environment may affect employee health and wellbeing. The aim of this study is to examine the relations between one model of work stress: the effort-reward imbalance model and building related symptoms in OFFICAIR study.

OFFICAIR is a cross-sectional survey conducted during the winter 2011-2012 in eight European countries. Building characteristics were collected using a checklist during a walk-through in 167 office buildings. Furthermore, 7441 office workers filled out an on-line survey questionnaire. This questionnaire included questions about socio-demographic data, lifestyle, work data, psychosocial environment, personal and familial medical history of diseases, physical state and psychological characteristics.

Multivariate hierarchical logistic regression models were used to determine the relations between psychosocial work environment and health symptom groups.

After adjustment for risk factors / confounders, increased risks of eye irritation, upper respiratory symptoms, general symptoms and skin symptoms among office workers with high efforts and low rewards were observed.

This study emphasizes the potential impact of work-related stress on health among office workers. The findings suggest that the burden of disease could be prevented by strengthening healthy work environment. Psychosocial factors should be examined when studying relations between indoor environment and health / wellbeing.

[Paper ID462](#)

EVALUATION OF ENVIRONMENTAL SURFACE CONTAMINATION IN MEDICAL EXAMINATION ROOMS USING AN ATP MEASUREMENT SYSTEM



ATP measurement method; Contact infection; Medical Examination Room

Matsumura, M. ,

The objective of this study was to identify high-risk areas for contact infection by investigating incidences of contamination in hospital medical examination rooms and reviewing previous studies on the operating ranges of health care workers and patients. Investigation of contaminants was conducted using an Adenosine tri-phosphate (ATP) measurement method (EnSURE® & SuperSnap™; Hygiena, Camarillo, CA, USA) of 12 surfaces in two examination rooms. We detected an increase in contamination greater than 1000 relative light units (RLU) per 100 cm² on the handrail of the doctor's chair, the doctor's desk, and the inner doorknob over the time medical service was provided.

The doctor's desk and the handrails of the doctor's chair were highly contaminated, and this correlated with a longer time spent near these surfaces [1]. It was noted that doctors may lean on a handrail or a backrest for fatigue relief during a long medical examination. The extension of the handset was highly contaminated surface with greater than 1000 RLU detected both before and after work. It was speculated that medical workers were not as careful to clean because patients do not contact this place. It was suggested that the strength of contacting pressure make difference in contamination.

[Paper ID463](#)

COMFORT IN NATURALLY VENTILATED OFFICES: IN-SITU MEASUREMENTS

comfort; in-situ measurements; natural ventilation

Pollet, I. , Bruyneel, G , Vens, A ,

Naturally ventilated offices are preferred by many people due to specific benefits as interaction with outdoors (air, temperature, daylight, ...), natural environment, less cooling consumption, less space loss due to technics, straightforward to understand, ... However, applications of natural ventilation in offices are rather limited. In this paper the indoor environment of the naturally ventilated Renson landscaped office, that is in use for ten years now, is measured and analysed according to the EN 15251 for parameters like (local) thermal comfort, indoor air quality, humidity, lighting and noise. Overall, one can see that -even though the occupation level is doubled in ten years and exceeds the planned occupation level- more than 75% of time the limits of category I are fulfilled. Only for CO₂ this is not the case, due to the high occupation level. Nevertheless occurrence in category III is limited to 24%. Category IV is never reached.

Comparing a VOC sensor (AppliedSensor) with CO₂ sensors revealed that the VOC output is equal or higher than the CO₂ concentration, even during non-occupied hours.

[Paper ID464](#)

SETTING INDOOR AIR QUALITY GUIDELINES IN FRANCE: 10 YEARS OF EXPERT ASSESSMENTS

Guideline; health; indoor air

KEIRSBULCK, M. K. , POUZAUD, F.P. , PERNELET-JOLY, V.P.J. , ROUSSELLE, C. , BOULANGER, G. ,



Introduction: Indoor air quality guidelines (IAQG) values correspond to safe levels below which adverse health effects are not expected to occur in the general population, including sensitive groups.

Methods: To determine IAQG values, ANSES' methodological guidelines is based on toxicological profiles, identification of critical effects and modes of action, the review and analysis of available guideline values or toxicological reference values to formulate recommendations.

Indoor air pollutants were ranked according to their health effects, and frequency and intensity of exposure in different indoor environments to identify a list of substances of concern.

Results: A methodological approach was published in 2007 and updated in 2011. Based on the ranking of indoor pollutants, 11 pollutants were assessed by an expert committee: formaldehyde, carbon monoxide, benzene, naphthalene, particulate matter, trichloroethylene, perchloroethylene, hydrogen cyanide, nitrogen dioxide, acrolein and acetaldehyde.

IAQG values were set in accordance with selected critical effects, modes of action and realistic exposure times. We will present a synthesis of our determined IAQG values for the pollutants studied and compare them with those recommended by the WHO in 2010.

[Paper ID468](#)

DESIGNING HEALTHY AND ENERGY-EFFICIENT SCHOOL BUILDINGS: COPING WITH CONFLICTING REQUIREMENTS

energy; IEQ; school

Cox, C.,

School buildings designed according to the Dutch 'Frisse Scholen' concept aim to combine a high indoor environmental quality (visual comfort, acoustic comfort, thermal comfort, indoor air quality) with low energy use. When designing buildings according to this concept, the different indoor environmental quality (IEQ) factors and energy-efficiency often result in conflicting choices. In this paper, an overview is given of design solutions chosen in 2 case studies. Both the buildings meet the requirements of the 'Frisse Scholen' program. An inventory of conflicting choices for different IEQ factors and energy efficiency was made. An analysis of the chosen solutions is given, resulting in an overview of lessons learned.

From the analysis, several conflicting choices have come forward:

- daylight versus energy use
- acoustic quality versus thermal mass (thermal comfort, energy use)
- daylight versus thermal comfort
- energy use versus thermal comfort

From the case studies, it shows that when designing healthy and energy-efficient school buildings, an optimal score for all parameters (IEQ and energy), by definition, is not possible. Based on the consequences resulting from the different quality levels (IEQ and energy), a careful selection of the required quality levels should be made by the principal and his consultants.



[Paper ID469](#)

COMPARISON OF WORKPLACE ENVIRONMENT AND ENERGY CONSUMPTION IN GREEN BUILDING BY IMPROVING OPERATION DURING SUMMER

Desiccant Air Conditioner; Personal Diffuser; Questionnaire Survey

Aoki, GA. ,

The purpose of this research is to investigate whether a difference in operations affects comfort and energy efficiency in a green building. In this research, a questionnaire survey, field survey, and analysis of operation data were conducted during the summer of 2013 in an office room installed with several green technologies. In the summer of 2012, the air temperature and relative humidity were set at 27 °C and 45%, respectively, and personal diffusers were used with free control. On July 30 morning in 2013, the relative humidity was set at 40% using desiccant air conditioner and all personal diffusers were switched on. The temperature in the office remained at 26.5–27.9 °C in both years. The humidity fell from 45–55% in 2012 to approximately 40% in 2013. During this year, the number of occupants dissatisfied with the indoor thermal environment decreased by more than 10%. The usage rates of personal diffusers may hardly affect the total amount of primary energy consumption in 2013. From this result, it can be concluded that switching on all personal diffusers in the operation will improve the satisfaction of occupants without increasing the total amount of primary energy consumption.

[Paper ID470](#)

PREDICTIVE MODELLING OF INDOOR FORMALDEHYDE AND SEMI-VOLATILE ORGANIC COMPOUNDS BASED ON AIR SAMPLING AND DESCRIPTIVE QUESTIONNAIRE DATA

indoor air; model; semi-volatile organic compound

Dallongeville, AD. , Banerjee, SB , Zmirou-Navier, DZ , Le Bot, BLB , Costet, NC , Deguen, SD , Annesi-Maesano, IAM , Blanchard, OB

Considering the increasing prevalence of airways inflammatory conditions in children worldwide, risk factors like exposure to indoor pollutants such as volatile and semi-volatile organic compounds (SVOCs) are of growing interest.

Indoor measurements were carried out in 150 French dwellings to assess concentration of formaldehyde, 7 phthalates and 2 synthetic musks. Occupants of each dwelling completed a questionnaire to describe their living-habits and the characteristics of the dwelling.

Concentration and questionnaire data were linked using multivariate linear regression models. Formaldehyde was detected in every dwelling. Consistently with the literature, its concentration was under the influence of the age of the building, relative humidity, presence of laminated flooring and aeration habits. Regarding SVOCs, our concentration data support the few available studies in French dwellings, 3 phthalates and the 2 synthetic musks being present in 100% of the homes. Among their determinants, presence of wallpaper or of vinyl flooring, higher temperature and relative humidity and smoking were positively associated with concentrations of most compounds. However, performance of these models were lower than the one for formaldehyde, thus pointing gaps in our knowledge about these compounds and their determinants.



[Paper ID471](#)

VERIFYING THE VALIDITY OF FACADE DESIGN STRATEGY THROUGH OPTIMIZATION OF DIGITAL MODELING TOOLS

Daylight harvesting; Facade design; Parametric design

Nagoshi, MN. ,

The purpose of this study was to verify the validity of facade design strategy by optimization using digital modeling tools. A general office was simulated and a digital model of the room was created using 3D modeling tools. A lattice-type louver was chosen and a genetic algorithm was used to optimize the depth of the louvers and their spacing. As a result, the outer cover of the facade performed well enough to pass less than 300 MJ/m²-yr, which is an energy-saving standard for offices in Tokyo.

We verified this performance experimentally using a physical model. The facade was shaped using a 3D printer and attached to a box-shaped model at 1/10 scale. Illumination and other factors inside the model were measured 5-times/day. During the experiment, eight subjects were asked to look inside the model to evaluate the interior lighting. For this reason, desktop illuminance was kept within the range of 500-1000 lux throughout the day. It was also shown from questionnaire results that the sensation of this level of brightness caused little dissatisfaction. These results verified that the performance of the high outer cover contributed to energy savings, and that the facade created little dissatisfaction regarding visual comfort.

[Paper ID472](#)

PROPOSAL OF RELEVANT SUBSTANCES FOR THE LABELING OF EMISSIONS FROM FURNITURE

emission; furniture; VOC

Leroux, CL. , Verines, LV , Le Bot, BLB , Glorennec, PG , Locoge, NL , Maupetit, FM , Boulanger, GB ,

French regulations stipulate that information on VOCs emissions from construction products and furnishing must be provided to users through a mandatory labeling scheme. Since September 2013, building and decorative products are labeled according to their emissions of VOCs. Concerning furniture products, French ministry requested the ANSES to provide an expertise on VOC's emissions from these products in order to prepare the future labeling.

A review of the international literature and labels was conducted in order to identify substances potentially emitted from furniture. In addition emission from 40 furniture products from the French market were tested in laboratory. At last, a total of 500 substances emitted from furniture have been listed.

Considering the lack of exposure data, a ranking method based on hazard was applied. A score, based on the CLP Regulation and the IARC classifications, was attributed to each substance. Substances with the highest scores were selected and discussed according to other criteria. A final list of around 10 substances to be included in the future furniture labeling will be presented. For each individual compound, a Lowest Concentrations of Interest associated with hazard effect will be calculated from exposure scenarios and toxicological reference values.



[Paper ID473](#)

VENTILATION RATE IN DWELLINGS AND ITS ASSOCIATION WITH CHILDREN'S HEALTH IN TIANJIN, CHINA

air change rate; dwellings; health

Hou, J. , Sun, YX , Kong, XR , Wang, P , Zhang, QN , Sundell, J

Ventilation is an important factor in indoor environment with regards to occupants' health. Few studies have been carried out in China to measure ventilation rate in residential buildings and to study its health effects. In order to investigate ventilation rate in homes and its association with occupants' health, a study on ventilation and children's asthma and allergy was launched at Tianjin, China. This is a nested case-control study. The concentrations of CO₂ in living room, children's bedroom and other room were measured. Questionnaires were used to survey health outcomes (such as asthma and allergy, respiratory infections, sick building syndrome symptoms) of the occupants. 266 dwellings in Tianjin, China were inspected and measured. In winter, the median value of average CO₂ concentrations was 1388 ppm and air change rate of homes was 0.37 h⁻¹. There were significant differences in the prevalence of asthma and allergy of children in homes with different ventilation rates. Lower ventilation rate may lead to a higher prevalence rate of asthma and allergy among children.

[Paper ID474](#)

SEASONAL VARIATION IN INDOOR ENVIRONMENTAL QUALITY IN NON-RENOVATED AND RENOVATED MULTIFAMILY DWELLINGS IN SLOVAKIA

Carbon dioxide; Energy retrofitting; Residential building

Földvry, V. ,

This study investigates the impact of energy renovation on the indoor environmental quality of apartment buildings during summer and winter months. The study was performed in three pairs of residential buildings. One of the buildings in each pair has been renovated and the other was in its original state. Both objective measurements and subjective evaluation using questionnaire have been used. Temperature, relative humidity and the concentration of CO₂ were measured in the bedrooms of the apartments. In winter, the average CO₂ concentration during night was higher in the renovated buildings. In summer, the average night-time CO₂ concentrations were similar in both types of buildings. The average air change rate in the original buildings was significantly higher than in the renovated buildings in winter, but not in summer. The larger fraction of occupants in the renovated homes that changed their ventilation habits in the summer compared to winter may partly explain the lower CO₂ concentrations and better perceived air quality in the renovated buildings than in the original buildings in the summer, as opposed to the winter. The current study indicates that large-scale of renovations may reduce the quality of the indoor environment in many apartments, especially in the winter season.

[Paper ID476](#)

CASE STUDY ON THE ACTUAL DESIGN AND OPERATION OF A RADIANT COOLING AND HEATING SYSTEM IN JAPAN

Case study; Radiant cooling and heating system; Thermal comfort

Miyashita, Y.M. , Tanabe, T.S , Kuzuu, E.K , Ishii, Y.I



A case study was conducted for the purpose of revealing the trends in use as well as the design and operation of radiant cooling and heating systems in buildings in hot and humid areas such as Japan. Documentary research was first conducted to reveal the trends. Next, questionnaires were given to facility engineers to determine attitudes toward the systems, as well as ideas and any problems in planning for and operating the systems. Facility engineers were also surveyed to collect information on existing installations of radiant ceiling systems, as well as detailed plans, design aims, and practical use conditions. It was revealed that water-based radiant cooling and heating systems account for about 70% of existing systems in Japan, and air-based or combined systems account for about 20% of this population. The main problems with integration of these systems are high initial costs and humidity regulation difficulties. In order to regulate humidity, a desiccant air-conditioning system was adopted in 13 out of the 17 cases. There are five general types of radiant systems. Also, the laying area rate of water-based systems is about 50-60%. On the other hand, for some air-based systems, the laying area rate is about 25%.

[Paper ID477](#)

CREATING A NET ZERO ENERGY HOUSE IN JAPAN

Solar Power; Thermal Environment; Zero Energy House

Matsunaga, TM. , Tanabe, ST , Nagasawa, N , Hayashi, H , Watanabe, W ,

In January 2014, "Energy Management House" was held in Tokyo, Japan. It is a net Zero Energy House (ZEH) competition, or a kind of Japanese Solar Decathlon. Waseda University designed a ZEH titled Nobi-Nobi HOUSE, which showcased various advanced technologies and ideas. We reconstructed this ZEH in Shizuoka and measured the thermal environment, light environment, and energy balance in the two seasons following the competition. Measurements indicated that autoclaved lightweight concrete (ALC) panels used for interior walls have a heat storage effect and that the room air conditioner consumes a lot of the energy in summer. Therefore, operations connected with the thermal environment and equipment by home energy management system (HEMS) is essential for attaining ZEH status. This paper will present the concepts of the Nobi-Nobi HOUSE and the results of the field survey.

[Paper ID479](#)

HOUSE OF TOMORRIW TODAY, SUSTAINABILITY ANALYSIS

Active House; Slimbouden; Sustainability

Lichtenberg, J.J.N. , Mak, J.J.P. , Dekker, H.C. den,



The House of Tomorrow Today (HoTT) is an experimental house built in the municipality of Heeze-Leende (Sterksel) in the Netherlands. It was named that way because it is realized according to rather new sustainable visions like Slimbouwen and Active House, but with tangible (today's) technology. The project was finished mid 2014 and is now subject of demonstration and research. The paper sets out the project, its objectives, the basic visions, research plans and especially preliminary findings with regard to sustainability analysis.

A suitable method that separately assesses and rewards main categories like related to adaptability, health and energy is GPR Building. This software tool is used to carry out the sustainability analysis.

Overall HoTT appears to be a very sustainable project as with regard to energy, health, user quality and long-term values. However with regard to the environment/materials the performance lags behind. Some sustainability elements appear to contradict. However, in HoTT the apparently poor score for environmental impact of materials is more than compensated by the energy production surplus. This phenomenon is being discussed, and also how to deal with it.

[Paper ID480](#)

USE OF A STEREOTHERMOMETER FOR MEASURING IN OPEN PLAN OFFICES DURING SUMMER PERIOD

Open plan offices; Stereotemperature; Stereothermometer

Zuská, L. , Kabrhel, M. K.

A study introduced field measurements of hygrothermal microclimate in building with open plan offices in the Czech Republic. Recent legislation in the Czech Republic introduces a new parameter for evaluation of indoor environment named a stereotemperature. The stereotemperature is measured by a newly developed instrument called a globe stereothermometer.

This work includes objective and subjective measurements. Questionnaires were filled by workers. The stereothermometer was used for the evaluation of non-uniform thermal microclimate conditions in the open plan offices.

The primary results of the subjective measurements of one occupants' group show problems with thermal comfort of the occupants.

The space was used as a referent object for the study to compare subjective and objective measurements. Based on the experimental and field measurements, a stereotemperature method will be described and evaluated.

[Paper ID481](#)

OCCUPANTS' PERFORMANCE IN OFFICE BUILDINGS AND INDOOR ENVIRONMENTAL QUALITY

occupants; office building; performance

Budaiova, Z.B. , Vilcekova, S.V. , Meciariova, L.M. , Meciariova, L.M.



The indoor environmental quality (IEQ) covers several factors, including thermal environment, indoor air quality, lighting, and acoustic. IEQ is important for the health, comfort, well being and performance of building occupants. A field study was conducted during the heating season in two modern office buildings in Slovakia. Air temperature, relative humidity, air velocity, sound pressure levels, concentrations of particulate matters, concentrations of total volatile organic compounds, concentrations of carbon dioxide and illuminance levels have been measured during the two testing days. The occupants performed 3 different tasks (text typing, arithmetical calculation, learning memory test) to evaluate their performance in monitored offices. The occupants were asked to work at their usual places and not to exert any special effort. Occupants of the offices evaluated subjective performance in relation to the perceived indoor environmental quality via questionnaires. Average values of sound pressure level were exceeded limit value (50dB) in both monitored offices. According to the physical measurements and the questionnaire the acoustical environment causes discomfort. Average performances of all tasks were higher in open space office. Total performance of occupants was higher than 84% in open space office and 92% in enclosed office.

[Paper ID482](#)

URBAN, BUILDING AND BEHAVIOURAL DETERMINANTS OF INDOOR HEAT EXPOSURE AND SUBJECTIVE HEALTH

health; heat; indoor

Duijm, F. , Loenhout, JAF van, Vink, NM , Greven, FE , Grand, A le, Zuurbier, MMM , Hoek, G ,

Elevated environmental temperatures are associated with health risks especially for elderly people. The elderly spent most of their time indoors. Outside and inside 113 dwellings of independently living elderly temperature and humidity were measured in spring and summer. Use of ventilation and sun blinds was registered in questionnaires, as were heat perception and health complaints during one baseline and three warm episodes without heat waves. We ascertained the contribution of outdoor temperature, building characteristics and occupant behaviour to indoor temperature, heat perception and health complaints. Indoor temperatures were significantly associated with outdoor temperatures and position in the building: ground floor, intermediate of under the roof. In bedrooms the size of windows at the east, south and west side was a significant factor. Other outdoor and building factors and registered use of ventilation and sun blinds had no significant contribution to indoor temperatures. Measured indoor temperatures had a strong relation to thermal comfort and health complaints of up to 40% of the occupants. Indoor relative humidity and outdoor temperature in the investigated situation did not contribute to the complaints. In the Netherlands exposure to heat depends mostly on building-related characteristics, to some extent on outdoor temperature and least on occupant behaviour.

[Paper ID483](#)

THERMAL ADAPTATION OF OCCUPANTS IN AN ATRIUM WITH ENVIRONMENTAL PREFERENCE

Field Survey; Semi-outdoor Environment; Thermal Comfort

Ikedo, N.I. , Tanabe, S.T , Nakano, J.N , Kato, S.K



The purpose of this study is to evaluate the thermal comfort of occupants in an atrium using spot cooling. In semi-outdoor environments, a comfortable environment cannot be efficiently created using the same means as for indoors. Thus, energy-saving method is becoming popular such as spot cooling. For this study, a field survey was carried out between July 2013 and January 2015 in the atrium of D- University. Air temperature, relative humidity, globe temperature, and air velocity were measured. Additionally, the occupants were given a questionnaire, and lastly a occupancy conditions survey was carried out. The results showed that in summer, there was a difference in air temperature distribution after operating the spot cooling. Regarding thermal environmental characteristics, it was shown that by placing furniture and air-conditioning facilities in term with different purposes, occupants have wider variety of adaptive opportunities. When it comes to thermal comfort, occupants' demand for controlling their thermal environment was stronger within the D- University atrium compared to either a non-air-conditioned or air-conditioned atrium. On the other hand, fewer occupants reported feeling uncomfortable. Thus, the occupants widely accepted their thermal environment by adapting themselves to their current conditions according to the type of air-conditioning system.

[Paper ID485](#)

TOWARDS TEMPERATURE LIMITS FOR MUSEUMS: A BUILDING SIMULATION STUDY FOR FOUR MUSEUM ZONES WITH DIFFERENT QUALITY OF ENVELOPES

Adaptive temperature limits; museums; simulation

Kramer, R.P., Schellen, H.L., Schijndel, A.W.M. van,

Controlling temperature (T) and relative humidity (RH) in museums is very important for collection preservation. However, recent research shows that many artifacts tolerate more fluctuations, certainly for T, resulting in the paradigm shift that RH is predominantly determined by collection requirements and T by thermal comfort requirements. More research should be attributed to thermal comfort in museums. Thermal comfort research in buildings shows that the PMV-model is valid for full air-conditioned buildings (HVAC), but not for naturally ventilated buildings (NV). Because many museums may be classified as HVAC-building, the PMV-model was used with typical input values for museums to develop temperature limits as a function of outdoor temperature. Building simulations have been performed of four museum zones with different quality of envelopes and various indoor climate conditions: a reference situation (20°C and 50% RH), existing Adaptive Comfort Guidelines and the PMV-based temperature limits developed in this study. The results show significant energy savings, revealing the importance of temperature limits for museums. Further research is needed to include the effect of expectation (psychological adaptation) and validation of the PMV-based temperature limits.

[Paper ID486](#)

WORKERS' SENSATION, COMFORT FOR INDOOR ENVIRONMENTS IN OFFICES PRIOR AND SUBSEQUENT TO THE EARTHQUAKE -THROUGH THE EXPERIENCE OF THE GREAT EAST JAPAN EARTHQUAKE IN 2011-

Earthquake; Field survey; Office worker

Utsumi, K.U., Tsushima, S.T., Tanabe, S.T.,



The Great East Japan Earthquake occurred on March 11, 2011 and caused a critical power shortage in a large area including Tokyo. Therefore, many offices implemented measures to save electricity, but previous research has shown that reduction in comfort and productivity occurred during the operation to save electricity. The purpose of this study was to determine the effect of having experienced the earthquake on office workers' sensation and comfort. Office workers from 21 office buildings completed 58 field surveys between 2003 and 2013, the results of which were analyzed. Results showed that, prior to the earthquake and in quake year, there was reduction in mean thermal satisfaction with SET* above 27°C, unlike those observed consequent to the earthquake. With respect to visual environment, there were no significant relationships between satisfaction and illuminance. Therefore, low illuminance was an effective means of saving energy while considering workers' psychological wellbeing. Results of the analysis indicated that workers' ranges of comfort were as follows: pre-quake: 25.3–26.1, quake year: 23.0–26.6, and post-quake: 20.8–27.4. Therefore, the range of workers' comfort expanded subsequent to the earthquake, due to changes in their emotions regarding indoor environment quality in thermal environment.

[Paper ID487](#)

ROLE OF OUTDOOR BIOGENIC EMISSIONS IN INDOOR SECONDARY ORGANIC AEROSOL FORMATION IN OFFICES

Biogenic emissions; Indoor air chemistry; Secondary organic aerosol
Carshaw, N. ,

In the developed world, we spend most of our time indoors and consequently receive most of our exposure to air pollutants there. In particular, energy efficiency measures reduce ventilation indoors and make buildings more airtight. This paper reports model simulations of indoor PM_{2.5} and ozone concentrations in an identical landscape office in three very different European cities: Athens, Helsinki and Milan. Indoor air quality has been investigated during an intense heatwave period in August 2003 and for the same period in 2009, which was a more typical summer. During the heatwave period, average ozone and PM_{2.5} concentrations were enhanced in all three cities relative to 2009 and were higher in Milan and Athens when compared to Helsinki. A significant portion (20-30%) of the indoor PM_{2.5} was derived from gas-phase chemistry outdoors initialised by biogenic emissions. Despite filtering inlet supplies to remove particles for office air, it may still be possible for outdoor chemistry to make a significant contribution to indoor particle concentrations. Such a contribution may increase in the future as outdoor temperatures increase through climate change, with predicted concomitant increases in ozone and biogenic volatile concentrations.

[Paper ID488](#)

PAPER_488_VERSION01 THE INFLUENCE OF LUNCH BREAKS ON AFTERNOON PRODUCTIVITY

Indoor environment; Lunch break; Productivity
Itoh, I. , Tanabe, S.T. , Matsunaga, T.M. ,



Recently, intellectual productivity has been considered important for working in offices. The factors that affect intellectual productivity during work include the indoor environment, tiredness, and job motivation. Activities such as social communication or refreshing oneself that lead to recovery from tiredness or increased motivation often take place during the lunch break. In this study, a questionnaire survey as well as physical environmental measurements and visual inspections were conducted to capture the effect of lunch breaks on office workers' intellectual productivity in the afternoon. Workers tended to be satisfied with the space when the room temperature or CO₂ concentration was lower. Workers who took naps, used the cafeteria or a relaxation space, or had high expectations of recovering from fatigue tended to report that their work efficiency increased. Further, there was tendency that the number of actions to recover from fatigue in the afternoon decreased as compared with those in the morning for those who had better satisfaction with the space where they spent most of their time during the lunch break. This suggests that how workers spend their lunch break has a positive impact on their afternoon productivity.

[Paper ID489](#)

AIRFLOWS THROUGH SINGLE HINGED AND SINGLE SLIDING DOORS DURING DOOR OPERATION IN ISOLATION ROOMS

Door type; Isolation room; Passage

Kalliomäki, PK. , Koskela, HK , Saarinen, PS , Tang, JWT

Patients with airborne infectious diseases are usually placed in negative pressure isolation rooms (NPIRs) in hospitals. The negative pressure is assumed to direct the airflow towards the isolation room and hence to prevent containment failures. However, door operation causes transient breakdown of these conditions during which airborne pathogens can disperse to adjacent spaces. Passage through the doorway increases this spreading as air is dragged out of the NPIR in the trailing wake of a passing person. The study presented here examines how different door types influence the doorway airflows under different ventilation rates, pressure difference and manikin passage. The performance of single hinged and single sliding doors will be analysed qualitatively with smoke visualizations and quantitatively by tracer gas measurements. The smoke visualizations illustrate qualitatively that operation of the hinged door creates more pronounced flow through the doorway than the sliding door. The tracer gas measurement results confirm this quantitatively as the air volume exchange through the doorway is found to be significantly smaller with the sliding door than with the hinged door. Additionally, ventilation rate and pressure difference had an effect although smaller than expected. On the other hand, the passage was found to contribute notably to the airflow.

[Paper ID490](#)

A COUPLED BES-ZONAL MODEL TO PREDICT STRATIFICATION IN A LARGE BUILDING

large building; preervation; thermal comfort

De backer, L.. , Laverge, J. , Janssens, A. , De Paepe, M.



In the past in a church no heating was foreseen and the indoor climate in the church was quite stable. After the Second World War the living standard of the people increased leading to higher comfort demands, not only in residential dwellings, but also in churches. As a consequence many heating systems were introduced that heated the whole indoor air volume of the church. Often these systems were rugged air inlets, designed to quickly heat a space without taking the effect of the fluctuating temperature and relative humidity on the artworks into account. Consequently, the many artworks in the church are also exposed to this changing climate, which led to faster deterioration or even to damage. To be able to evaluate the thermal comfort and the preservation conditions, reliable simulation tools are needed to predict the course of the surface and the indoor conditions of temperature and relative humidity. This paper tries to find a simulation strategy to analyse the indoor temperature and relative humidity in a church building. For this purpose the thermal-zonal model of Togari is coupled with the BES-software TRNSYS. Further, a case study illustrates the working of the model.

[Paper ID491](#)

VOC OR CO₂: ARE THEY INTERCHANGEABLE AS SENSORS FOR DEMAND CONTROL?

CO₂; Residential; VOC

Laverge, J., Vens, A., Pollet, I., Spruytte, S., Losfeld, F.,

VOC sensors are increasingly frequently introduced as a cheap and energy efficient alternative for CO₂ sensors in demand controlled ventilation systems. They do not, however, pick up pure CO₂. Additionally, there is no established correlation between total VOC concentration and perceived air quality. In this paper we investigate if the signal from a VOC sensor can be used to achieve similar flow rate control as obtained with a classic carbon dioxide sensor.

The comparison between VOC and CO₂ sensors was made through in situ measurements in 5 dwellings. The results show that, although there is a good correlation between the moments of high concentration, the fact that the VOC sensors are non-specific and therefore react to all pollution sources, makes them much more sensitive to use in a demand controlled ventilation system.

VOC sensors are promising but control algorithms need to be adapted to interpret their non specific signal to maximise IAQ.

[Paper ID492](#)

SLEEPING IN AN ACTIVE HOUSE: THE OCCUPANT'S EXPERIENCE

IEQ; Sleep; Survey

Laverge, J., Foldbjerg, P., Christoffersen, J.,



In a residential building, sleeping is, looking at the time involved, the most important activity of the occupants. None the less, optimizing the indoor environment for maximum sleep quality has received surprisingly little attention in literature and practise. There is therefore a dire need of data on occupant responses to indoor environmental conditions during sleep

The active house project sought to create a series of 'living labs' for dwellings. The houses were constructed along the principles outlined as the state of the art on indoor environmental performance based on a number of expert panel colloquia. Most of them have now been occupied and monitored for 1 or several years. In this paper we present the results of the monitoring campaign in the bedrooms along with subjective perceptions of the occupants about their sleep quality based on surveys. The results are compared to the scarce references that are available on the subject.

The results show that, when sleep comfort is considered, a number of traditional targets in HVAC design might need to be rethought: being able to achieve a relatively cool temperature, clean fresh air and deep darkness are relatively more important. .

[Paper ID493](#)

COMPARISON OF CONTROL STRATEGIES OF VENETIAN BLINDS REGARDING VISUAL AND THERMAL COMFORT IN SUMMER IN CLASSROOMS

control strategies; Monte Carlo; venetian blinds

Tschakrow, E. , Hellwig, RH

Automated external venetian blinds are often used for sun protection in classrooms. This study considers different control strategies for this application in summer season. The strategies are analysed regarding their impact on visual and thermal comfort such as heat protection, glare protection and visual contact to the outside. Possible strategies are compiled and specific control schemes are defined for a comparison. A discussion of visual and thermal comfort helps to select certain assessment measures which are required for the comparison. Thermal building simulation is used to calculate the assessment measures using a model of a typical classroom. In order to enlarge the validity of the results to a broader range of classroom models, certain model parameters with particular relevance are varied. This is realised using a Monte Carlo simulation which includes the sampling of random parameters within defined value ranges. Applying this method several hundred different classroom models are used for each control strategy. A comparison of the assessed control strategies helps to identify sensible control strategies which are combined in an optimised control scheme.

[Paper ID494](#)

NEUROTOXIC SEMI VOLATILE ORGANIC COMPOUNDS IN HOUSE SETTLED DUST: CONTAMINATION AND DETERMINANTS

indoor dust; source; SVOC

Le Bot, BLB. , Warembourg, CW , Mercier, FM , Gilles, ER , Raffy, GR , Blanchard, OB , Bonvallot, NB , Chevrier, CC , Glorennec, PG ,



People are exposed to multiple pollutants at home and especially children by dust ingestion due to hand to mouth contact. Among SVOCs found in indoor dust, some of them are considered or suspected to be neurotoxicants: polybrominated diphenyl ethers (PBDEs), polychlorobiphenyls (PCBs), pyrethroids, organochlorine and organophosphorous pesticides. This study aims to measure numerous neurotoxic SVOCs in indoor dust of children's home and study their determinants including house characteristics and people habits. 289 children's home from the PELAGIE mother-child cohort (France) were investigated (2009-2012) with collection of dust from domestic vacuum cleaners. The major SVOCs in home dust were pyrethroids (permethrin and cypermethrin) and BDE 209. Lindane, deltamethrin, tetramethrin, dieldrin, BDE 85, 99 and 100, and PCB 52, 101, 105, 118, 138, 153 and 180 were detected in 10-50% of dwellings. Before 1970's homes had statistically significantly higher concentrations of lindane, dieldrin and PCBs. Frequency of floor cleaning or window opening has been associated with reduced concentrations for lindane, dieldrin and some PCBs. Concentrations of pyrethroids increased with the reported household use of insecticides.

[Paper ID495](#)

DETERMINATION OF FUNGAL CONTAMINATION USING TOTAL FUNGAL BIOMASS

Cell equivalent; Ergosterol; N-acetylhexosaminidase

Mensah-Attipoe, J. , Pasanen, P. , Veijalainen, A-M. , Taubel, M. , Hyvärinen, A. , Rintala, H. , Reponen, T. ,

Ergosterol, β -N-acetylhexosaminidase (NAHA) enzyme activity and (1,3)- β -D-glucan are often used for the determination of total fungal biomass. The concentration of (1,3)- β -D-glucan has been shown to vary widely between different species, but much less is known about the variation in ergosterol or NAHA enzyme activity.

The aim of the current study was to determine the ergosterol and NAHA content of common indoor fungal species "Aspergillus versicolor Cladosporioides cladosporioides" and "Penicillium brevicompactum" looking at growth materials and age of culture.

Three building materials (green and conventional acoustic boards and wood) were each inoculated with the three test fungi. The materials were incubated for 0 days, 1, 2 and 4 weeks and fungal biomass determined by measuring the concentration of ergosterol as well as the enzyme activity of the fungi at the end of each time point. These values were normalized by the concentration of cell equivalents (CE) measured by quantitative PCR. The results showed that ergosterol ratios varied from 0.2 to 35 pg/CE. The respective range for NAHA was 23 to 58 $\times 10^{-3}$ U/CE. "C. cladosporioides" had the highest ergosterol and NAHA ratios. Wood had the highest ergosterol and NAHA ratios. Two week old cultures had the highest ergosterol and NAHA ratios.

[Paper ID496](#)

FACT FINDING SURVEY ON THE REGIONAL ENVIRONMENT AND THE PHYSICAL ACTIVITY AND EXERCISE HABITS OF JAPANESE CHILDREN

Accelerometer; Community; Logistic regression analysis

Omi, S. , Ikaga, T , Hino, K , Ando, S , Amemiya, T ,



With the recent reduction in physical activity seen in Japanese children, reduced ability to exercise and increasing prevalence of overweight and obesity have become serious health concerns. Therefore, governmental agencies have promoted the improvement of the regional environment to encourage physical activity in children. This study shows, using a questionnaire survey and actual measurement of physical activity of children and parents, that the frequency at which children use community centers and gyms and participate in community activities affects frequency of exercise. The number of daily steps in children who did not receive sufficient daily exercise (<10,000 steps/day) increased by about 3,000 steps/day when they participated in community activities.

[Paper ID497](#)

EVALUATION OF MOULD SAMPLING METHODS IN ASSESSMENT OF A BUILDING

Building ecology; Building microbiome; Microbial damages

Engh, I. B., Mattsson, J., Carlson, O. E.,

In this case we assessed different sampling methods based on molecular and morphological techniques available to the practitioner. Dust and air samples were taken to investigate indoor air quality in parts of several buildings in use.

Different levels of identification of the fungi present, and also differences in quantification of the fungal contaminants present were observed. In dust samples, identification resulted in less identified contaminants than compared to results from qPCR analyses of parallel samples. Air sampling resulted in the same level of variation in the identification process.

We conclude that although molecular based methods might seem to give more accurate results regarding identification and quantification of fungal spores and fragments in dust and air, the results will give little meaning to an unskilled practitioner set to assess IAQ.

We advise practitioners to supply their sampling procedure by traditional methods to detect microbial growth and also moisture measurements in order to find the source of mould contamination.

[Paper ID499](#)

THE EFFECTS OF LIGHT AND VISUAL ENVIRONMENT IN OFFICE SUPPORT SPACES ON FATIGUE, SLEEPINESS, AND WORKPLACE PRODUCTIVITY THROUGH THE AUTONOMIC NERVOUS SYSTEM

Autonomic Nervous System; Light and Visual Environment; Workplace Productivity

Ogawa, S., Ikaga, T., Ichihara, M., Harimoto, K



Improvements in workplace productivity bring significant benefits to companies, and so previous research has focused on how the indoor office environment affects workplace productivity. Recently, the effect of support spaces, such as “refresh corners”, on workplace productivity has been investigated. Light and the visual environment also affect the fatigue and sleepiness of workers through the autonomic nervous system. Hence, support spaces could improve workplace productivity by alleviating fatigue and sleepiness. In this study, we conducted a human subject experiment in the autumn of 2013. The working efficiency of participants was measured during simulated work while they used a support space with different light and visual environments. In addition, the participants wore a heart rate monitor to measure their autonomic nervous state and they answered a questionnaire on fatigue and sleepiness before and after support space use. An open support space activated the parasympathetic nervous system and reduced fatigue. Moreover, having blinds open to allow daylight in also activated the sympathetic nervous system and decreased sleepiness. Lower levels of sleepiness before work improved working efficiency for idea generation. These results suggest that using open support spaces with daylight reduces fatigue and sleepiness, and increases workplace productivity.

[Paper ID500](#)

MIGRATION OF PCBs FROM SEALANTS TO ADJACENT MATERIAL

Concrete; Migration; PCB

Andersen, HVA. , Gunnarsen, L , Kampmann, K ,

PCB in sealants can migrate into porous surfaces like concrete and brick and contaminate these materials. The study focuses on an analysis of concentration profiles in relation to alleviation of PCB contamination. The PCB content was determined in 20 samples of concrete and 6 samples of brick adjacent to outdoor PCB-containing sealants. The samples were submitted to the laboratory for normal commercial assessment of PCB content in relation to the handling of waste from renovation works in Denmark. The results showed that the PCB concentration in the sealant not necessarily relate to the concentration of the adjacent material. The profiles of PCB concentration into the materials showed some variation, though in general there is a tendency of relative higher concentration near the primary source in concrete and longer migration at low concentrations in brick. The concentration profiles seemed to fit an exponential function for concrete and a power function for brick. Based on the sample series, a worst case scenario for migration was defined. For concrete, it showed that a concentration of less than 50 ppm in the material (hazardous waste) was reached at a distance of 5 cm, whereas for bricks the distance was 3.5 cm.

[Paper ID501](#)

AGE CORRECTION IS NECESSARY WHEN APPLYING COMPUTER DISTRIBUTED QUESTIONNAIRES FOR CHILDREN'S EVALUATION OF SCHOOL INDOOR ENVIRONMENT.

Indoor environment; Questionnaire; Schools

Holøs, S. B.. , Høiskar, B.A.H. , Gustavsen, K. ,



A computer-distributed adaptation of the MM ('Miljømedicin' - Environmental Medicine) basic indoor environment questionnaire was answered by 4156 pupils, aged 9-19. Prevalence of most of the symptoms and conditions correlated positively with age. General symptoms like fatigue, 'heavy headedness' and difficulty to concentrate showed particular strong positive correlation with age, with prevalence increasing 2.1-6.2% per year of increased age. The younger children reported more annoyance from dim lighting, noise and heat and glare from the sun, while the older were more annoyed by too cold or draughty rooms or bad perceived air quality. Different preferences, behavior, physiological or psychological factors as well as external confounding factors between the different ages may all contribute to the observed differences.

The observed correlation with age may seriously distort the comparison between different schools or school buildings if not accounted for.

In conclusion, data distributed questionnaires can be useful tools for mapping indoor climate at schools, but correction for age will generally be necessary.

[Paper ID502](#)

SENSOR CONTROLLED VENTILATION CONTROL STRATEGIES: A REVIEW

Control strategy, Occupant needs, Energy efficient; Indoor air quality (IAQ); Sensor
Tang, J. ,

Ventilation control strategy plays key role in reducing overall building energy consumption. This is especially true for control system employing sensing, monitoring and actuating sub-systems. These systems take into account occupants comfort (that is, desired indoor air quality (IAQ) and thermal comfort) in building energy management. Ventilation control strategy based on terminal users has attracted increased attention from researchers. This paper reviews studies on ventilation sensor technologies with regards to occupant's IAQ requirements and control strategy. The applicability and restriction on usage of various sensors and ventilation control strategies are reported on. Evidence from reviewed publications with certain theoretical assumptions suggests that most of the proposed control strategies could reduce energy consumption. Various sensors are recommended to integrate with each other to obtain actual occupant level as well as to optimize IAQ and energy saving.

[Paper ID503](#)

INDOOR CLIMATE AND USER SATISFACTION IN CLASSROOMS AFTER ENERGETIC RETROFITTING

classroom ventilation; indoor climate; retrofitting, user satisfaction
Hackl, M.K. , Hellwig, Runa Tabe , Maurer, Julia ,



Retrofitted classrooms are supposed to provide a better indoor environment and hence to have more satisfied occupants. The aim of this study was to survey the indoor climate in retrofitted, mechanically ventilated classrooms, to gain knowledge of the occupants' perception of the indoor climate and their perception of the newly implemented ventilation systems. Subjective and objective data from 32 mechanically ventilated classrooms in 17 Bavarian schools in Germany was collected. In each classroom outdoor and indoor air temperature, relative humidity and CO₂ concentration were measured for at least one week between May and July 2014. In addition teachers, pupils and caretakers were asked to fill in a questionnaire concerning user perception, behaviour and satisfaction. During lessons, classrooms showed median CO₂ concentrations between 750 and 2110 ppm, with 90% of all values below 1490 ppm. During lessons, 72% of all measured indoor air temperatures were between 23°C and 26°C. The evaluation of the questionnaires shows dissatisfaction with indoor air temperatures in summer, available controls and a need for improved information. Taking into account the high expectations of especially the teachers, the majority of the other users proved to be satisfied.

[Paper_ID504](#)

IMPROVING THE ENERGY- & IAQ PERFORMANCE OF VENTILATION SYSTEMS IN DUTCH RESIDENTIAL DWELLINGS

Energy performance; IAQ-performance; Ventilation Systems

Holsteijn, R.C.A.,

MONICAIR is a pre-competitive field research project of a broad consortium of Dutch ventilation unit manufacturers and research institutes, supported by the Dutch government. First aim of the project is to investigate the indoor air quality (IAQ) performance and energy characteristics of 10 different mechanical ventilation solutions in dwellings that meet strict air-tightness standards and comply with current building regulations. Second goal is to further improve the ventilation systems on energy and IAQ-performance.

Over a full year 62 residential dwellings were monitored, with in each habitable room sensors for occupancy, CO₂, relative humidity and air temperature. Energy consumption of the mechanical ventilation units and space heating boilers were continuously monitored.

Although all systems comply with building codes, the data show huge differences in both the IAQ- and energy performance. Real life CO₂-excess dose (above 1200 ppm) may vary from 10 to 850 kppmh per person per heating season, resulting in a situation in which respectively 1 to 85% of the time spent at home, the ventilation is not sufficient in the room that one occupies.

Especially in bedrooms concentrations of well above 3000 ppm were measured. Also real life primary energy consumption for mechanical ventilation show large differences.

[Paper_ID505](#)

METHOD FOR ACCURATE MEASUREMENT OF CAPTURE EFFICIENCY OF COMMERCIAL KITCHEN HOODS CONSIDERING RECAPTURE CONDITIONS

capture efficiency; commercial kitchen; recapture

Hori, T.H., Kurabuchi, T.K., Toriumi, Y.T., LEE, S., Okamoto, R.O., Okuda, A.O., Komatsu, H.K., Aibara, M.A



From the perspectives of comfort and reduced energy use, the capture efficiency of a hood is a crucial index to determine the required ventilation (air flow-rate) for a commercial kitchen. For this reason, more precise measurement of capture efficiency is required. Conventionally, its measurement is done in a laboratory with a high ceiling. In this study, a method is proposed to measure capture efficiency in a laboratory of normal ceiling height, and to verify the validity of the method. The basic measurement technique is to minimize the influence of recapture by appropriately adjusting the ceiling-exhaust air flow. At times, the influence on recapture by ceiling exhaust cannot be completely eliminated. In this case, estimating the background concentration affecting recapture, using the Extrapolation of Tracer gas concentration Decay (ETD) method (based on concentration decay after the tracer gas supply stops), is used to calculate the capture efficiency. In addition, in this study, measurements in a laboratory with a high ceiling were compared with those in a laboratory with a ceiling of normal height. This confirmed that the capture efficiency modified by the ETD method, matches the other.

[Paper ID506](#)

THE EFFECT OF HIGH AIR TEMPERATURE AND CO₂ CONCENTRATION ON HUMAN SUBJECTIVE RESPONSES

High CO₂ concentration; High temperature; Subjective responses

Liu, L. , Wargocki, W

Human subjective (psychological) and objective (physiological) responses under high air temperature and CO₂ concentration were studied. 12 healthy subjects (6 male) were recruited for an experiment in a climate chamber. Three experiment conditions were designed: 26 °C/380 ppm, 35 °C/380 ppm and 35 °C/3000 ppm. In the experiment (3 hours), subjects' thermal comfort, SBS symptoms, perceived air quality and self-estimated work performance were investigated with questionnaires. The results indicated that high temperature had significant effect on subjects' subjective responses. However increasing CO₂ concentration to 3000 ppm at 35 °C did not further change the subjects' subjective thermal responses.

[Paper ID507](#)

A STUDY ON THE BEHAVIOUR AND CONTROL OF MICROBES IN AIR CONDITIONING SYSTEM

air conditioning system; microbial contamination;

Watanabe, R. ,

The inside of an air-conditioning (AC) system is suitable for multiplication of microbes, and it is known that the microbial contamination will affect the indoor air quality (IAQ). For reducing the indoor air pollution in connection with microbes, it is important to clarify quantitatively the actual contamination status of the microbes in an AC system which greatly affects the IAQ. On the other hand, cleaning of an AC system (duct, air-conditioner) is ineffective as a measure of the microbial contamination. This paper reports the results obtained by the survey about the actual status of microbes in air-conditioning systems equipped in ten office buildings in Tokyo area, Japan.

[Paper ID508](#)

COMPARISON OF PORTABLE AIR CLEANER REMOVAL EFFICIENCIES FOR BIOAEROSOLS BETWEEN THE DECAY METHOD AND THE SINGLE-PASS METHOD



Bioaerosol; Portable air cleaner; Removal efficiency

Yamatani, Y. , Yanagi, U.

It is well known that a portable air cleaner is effective in the removal of suspended biological particulate matter (bioaerosols). However, a formal valuation method of the purification performance of an air cleaner has not yet been reported. The equivalent air change rate is advocated as an index of the purification performance of an air cleaner. This index is based on the bioaerosol concentration decay method, which uses a chamber. A valuation method by the single-pass method for the performance of an air cleaner has also been used to measure the performance of an air cleaner. This study compared the purification performance between the decay method and the single-pass method. After stopping the generation of bacteria in an experimental chamber, the suspended bacteria in the center of the chamber (point A) were sampled several times by filtration. Simultaneously, the concentration of suspended bacteria in the supply air of an air cleaner (point B) was also measured. The removal efficiencies of the decay method and the single-pass method can be obtained by using the data of point A, and the data of both points A and B, respectively. The results of the decay method and the single-pass method were almost the same.

[Paper ID509](#)

CHARACTERISTICS OF THERMAL COMFORT AT ELDERLY CARE CENTER IN SEOUL, KOREA

elderly; elderly care center; thermal comfort

Yang, J.H. , Nam, I.S , Kim, J.M , Oh, H.J , Lee, D.H , Sohn, J.R

The demand for specialized care service facilities for elderly, such as elderly care center (ECC), has increased (Damiani et al., 2009). On average, older adults have a lower activity level, and thus metabolic rate, than younger persons, which is the main reason that they require higher ambient temperatures.

The previous studies have generally focused on adults and students, however, needs to study on thermal preferences for elderly exist (van Hoof, 2008). Elderly are more susceptible to health problem by the effects of exposure to indoor environments due to the elderly stay indoor more (Mendes A et al., 2014) and decline in immune system (Ginaldi L et al., 1999). Also, metabolic rate in elderly is reported to be lower than in adults. Therefore, elderly would require a higher ambient temperature also in resting conditions

The aims of this study was to characterize thermal environments preferred by elderly stayed in ECC in Korea in order to propose a new PMV model for elderly.

[Paper ID510](#)

INDOOR AIR QUALITY IN EDUCATIONAL ESTABLISHMENTS: A PROPOSED FRAMEWORK FOR ENGAGEMENT AND EMPOWERMENT

engagement; INDOOR air environment; schools

Høiskar, B.A.K.H. , Bugge, EB , Kobernus, MK , Gustavsen, KG



A major challenge to improving Indoor Air Quality (IAQ) in schools is both awareness of the current situation, and the engagement of those who can make a difference. In this paper, we propose a framework for improving IAQ in schools, promoting better awareness, engagement and co-operation between stakeholders and consequently improving IAQ. This framework has been tested across several municipalities and schools within Norway with consistent results. The framework has five main elements: 1) school management and staff identify and document potential problems causing poor IAQ through a structured photo process 2) Meetings with relevant stakeholders, 3) Assessment of IAQ, 4) Identify potential problems and develop an action plan and 5) Report with findings from the process.

The framework was tested in six schools and has proven to be successful. The main outcomes of the project are: 1) positive response from the school administration on improved IAQ achieved at low cost, 2) Systematic and practical approach to IAQ maintenance, including sharing of well-defined responsibilities and activities amongst stakeholders, 3) Better co-operation and raised awareness of IAQ among all stakeholders. The field tests have shown that active participation of staff and students is a key element in improving IAQ in schools.

[Paper ID511](#)

TAKING THERMAL REGULATION MODELS FROM THE LAB TO THE WORLD: ARE CURRENT VIEWS READY FOR THE CHALLENGE?

case study; thermal models; Thermal regulation

Veselá, S. , Kingma, B. , Frijns, A. ,

Current thermoregulation and coupled thermal sensation models are mostly based on and validate for laboratory settings. In order to investigate the performance of a thermoregulation model in practical settings, this study collects data in experiments undertaken in everyday situations from sitting in the office (1 met) to walking outdoors (2.8-2.9 met). Also, the clothing consists of realistic outfits with a variation in upper body clothing insulation (0.55-1.14 clo). Six combinations of activity levels and insulation values are followed by 3 male and 2 female individuals. Overall, the computed mean skin temperature is in good agreement with measured data. For averaged distal skin temperature (hand and foot) high variations are found. The temperature deviation might be caused by either false heat delivery via skin blood flow or misestimated heat losses. For further research it is suggested to measure skin blood flow in similar experiments. A difference between male and female subjects is seen especially for proximal skin temperatures (thorax and abdomen). Therefore, physiological differences between males and females have to be incorporated in the model. Furthermore, clothing insulation has an impact on the temperature differences of the data and hence, also needs revision especially with regard to local insulation values.

[Paper ID512](#)

HOW PHYSIOLOGY SHAPES THE NEUTRAL THERMAL ENVIRONMENT.

Biophysical comfort model; Thermal comfort;

Kingma, B.R.M. ,



Odds are that you and I appreciate our thermal environment differently. Individual differences in metabolism (e.g. activity), body insulation (e.g. body fat) and thermoregulation (e.g. ability to change body insulation via skin blood flow) influence the optimal environment with respect to body heat balance and thermal comfort. In this paper a biophysical model is used to specifically distinguish thermal neutrality and thermal comfort in lean vs. obese adults. Thermal neutrality is the range of operative temperatures where the body can solely rely on skin blood flow to regulate body core temperature (e.g. does not require (non)-shivering thermogenesis or sweating). Thermal comfort is the range of operative temperatures where a person expresses satisfaction with the thermal environment. Individual differences in body insulation are most pronounced in lean vs. obese but also present in males vs. females. Existing comfort models (e.g. Fanger) take into account the effect of metabolic rate. However, as shown here, the effect of body insulation cannot be neglected. The model presented in this paper takes into account the primary physiological parameters for thermal comfort. Therefore, this model allows for design of thermal environments that are better tuned to requirements of specific user groups while performing daily activities.

[Paper_ID513](#)

LOCAL COOLING IN A MILD HOT ENVIRONMENT

Local cooling; Mild hot environment; Thermal comfort

Pallubinsky, H. , Schellen, L. , Rieswijk, T.A. , Breukel, C.M.G.A.M , Kingma, B.R.M. , Marken Lichtenbelt, W.D.

In the recent years, overheating of buildings is a hot topic in the Western World. One third of the primary energy supply is used for ventilating and air-conditioning of commercial and public buildings. However, occupant thermal comfort is often not achieved. It is hypothesized, that individualized local cooling is an effective way to improve occupant thermal comfort in a warm condition. This study aimed to evaluate the effect of five different local cooling techniques on thermal sensation, thermal comfort and skin temperature of male and female subjects. 16 healthy, young subjects (8 male, 8 female) were exposed to 5 local cooling conditions (face, underarms, back, feet and face combined with underarms) in a mild hot thermal environment ($32.3 \pm 0.3^\circ\text{C}$). The cooling conditions were compared to periods of 'no cooling'. Based on preliminary results, only face cooling and combined face-underarm cooling significantly improved thermal sensation and thermal comfort. We did not detect differences in thermal sensation and/or thermal comfort between men and women with respect to the five cooling conditions. We conclude that 'face cooling' and combined 'face-underarm cooling' are effective ways to improve thermal comfort and thermal sensation of males and females in a mild hot thermal environment.

[Paper_ID515](#)

COMPARISON OF THERMAL COMFORT AND SENSATION SCALES – A CASE STUDY

Scales; Thermal comfort; Thermal sensation

Veselý, M. , Li, R , Zeiler, W ,



Thermal sensation is a conscious feeling that grades the thermal environment, while thermal comfort expresses satisfaction with this feeling. Multiple scales to quantify thermal sensation and comfort have been developed throughout the history of research on thermal comfort.

In this paper, the most important scales for measuring thermal sensation are compared and evaluated. Of all scales, the ASHRAE 7-point scale (from cold, through neutral, to hot) is the most common. To measure comfort these scales are often presented together with an acceptability or a comfort scale. Another widely used scale, the Bedford scale uses also 7 points, but combines thermal comfort and sensation by coding from much too cool to much too warm with comfortable in the middle. The preference scale is to use to express whether the respondent would prefer warmer or cooler thermal environment.

To compare difference between different thermal comfort scales a case study was conducted, in which a number of respondents were asked to report their thermal comfort. Different scales were presented to the respondents under same thermal environmental parameters. The responses on different scales have been compared. The findings of this study can give a guidance to compare thermal comfort studies using different scales.

[Paper ID516](#)

METHODOLOGY FOR OPTIMIZATION OF ENERGY EFFICIENCY, INDOOR CLIMATE AND ECONOMY TARGETS IN MUNICIPAL BUILDING PROJECTS

Energy efficient construction; Indoor climate; Life-cycle economy

Vinokurov, M.V. , Luoranan, M.L. , Hammo, S. ,

Need to improve the energy and cost efficiency in public buildings is driven by tightening energy saving targets and the economic challenges of municipalities. Another important challenge is to preserve safe and comfortable indoor climate while implementing energy efficiency measures. This paper presents a methodology to promote energy efficiency, economy and indoor climate quality in decision-making related with realization of municipal construction project.

Energy efficiency, economy and indoor climate targets for the methodology were set based on principles of sustainable development. Life-cycle approach was used to assess how and where in the building's life-cycle it is the most effective to interfere in terms to achieve targets. The development was conducted by Lappeenranta University of Technology in cooperation with local municipal officials. Functionality of the methodology was tested on the actual construction project.

Systematical goal-oriented optimization of technological solutions along with appropriate project facilitation can lead to improvement of energy efficiency, economy and indoor climate of the building. Extreme attention should be paid to planning phase. Further development of the methodology and criteria should be continued. The extension of the scope of criteria to renovation projects and regional approach would also be important development steps.

[Paper ID517](#)

ASSESSMENT OF MOISTURE AND MOLD PROBLEMS – THE FINNISH EXAMPLE

Building investigations; moisture damage; Mold

Hyvärinen, A. , Täubel, M.



The Finnish Health Protection Act considers moisture and mold damage in a building as circumstances that may affect negatively on health and are thus treated as a potential health hazard that need to be removed. Here we present an approach on how to perform a building assessment for moisture and mold damage, integrating microbial measurements. This approach is being part of Finnish Healthy Housing Guidelines.

[Paper ID518](#)

QUANTITATIVE PCR IN MICROBIAL ASSESSMENTS OF INDOOR SPACES.

Microbes; Moisture damage; Quantitative PCR

Täubel, M., Niittynen, M., Jalkanen, K., Vepsäläinen, A., Reiman, M., Hyvärinen, A.

Microbial contamination of building materials, surfaces, or indoor air is traditionally assessed using cultivation technique in support of building investigations. Cultivation is still today the primary method of choice, despite the known short-comings of this approach. However, both in research settings as well as in practical situations, a shift towards DNA-based approaches for measuring microbial levels in indoor sample materials is noticeable. Knowledge is needed on the weaknesses, strengths, and especially the peculiarities of these 'new' methods, in order to facilitate their application beyond research. This work discusses such aspects for the quantitative PCR method, in comparison to traditional cultivation approach.

[Paper ID519](#)

EMPOWERING STUDENTS TO IMPROVE THEIR INDOOR SCHOOL ENVIRONMENT WITH THE HELP OF LOW-COST AIR QUALITY SENSORS –CITI-SENSE PROJECT

empowerment; Indoor environment; schools

Robinson, J.A.R., Holøs, S.B.H., Kåstad Høiskar, B.A.K.H., Kocman, D.K., Crawford, J.O.C., Keune, H.K., Jovašević-Stojanovic, M.J-S., Bartonova, A.B., Horvat, M.H.,

It is commonly reported that the physical and chemical environment at schools is often degraded, thus adversely affecting the well-being, health and learning performance of students. CITI-SENSE aims to increase citizen involvement in participatory air quality monitoring through incorporating data from static and portable sensor devices as well as subjective data on perceived air quality into Citizens' observatories. By doing so, it examines how technology and participative action can help communities and policy-makers work together in the decision making process to achieve desired environmental improvements. It provides assessment methods and resources for schools to monitor indoor air quality conditions and, through active participation of stakeholders, find solutions towards improvement. This concept is carried out across culturally, socially and geographically distinct settings in four cities (Belgrade, Edinburgh, Ljubljana and Oslo). In addition to developing robust methods, this allows us to examine the applicability of our approach in a wider region, which would enable upscaling. This will help provide solutions that maximize both technological and societal innovation in the field of environmental governance. CITI-SENSE project is co-funded from the European Union's Seventh Programme for research and technological development under grant agreement No 308524.



[Paper_ID520](#)

VISUAL DISCOMFORT MEASUREMENTS OF HEALTHCARE PROFESSIONALS IN NURSING HOMES

Indoor quality; Lighting; physical environment

Huisman, ERCM. ,

INTRODUCTION: (Day)light is a key concept for life enrichment care facilities. Light is important for our physical and psychological functioning. Lighting can have an impact on peoples' perceptions and response to the environment and also can improve the quality and overall experience of healthcare professionals (HP). We investigated which aspects contribute to the visual discomfort of HP in relation to the indoor environment of care facilities. METHODS: The study was done in two locations of a nursing home in the Netherlands. Light measurements were performed in common rooms of both locations. HP (N=40) of both locations filled out a questionnaire based on the Ocular Surface Disease Index (OSDI) and the Visual Discomfort Scale (VDS). RESULTS AND DISCUSSION: The results of the light measurements in the common rooms of both locations showed about half of the measured positions meet the recommended values of at least 750 lux for the horizontal and vertical illuminance. Preliminary results of the questionnaire raise the question of a difference between the two locations on ocular symptoms such as sensitivity to light and painful eyes and visual functioning. Consequently, future study is needed to determine how (day) light fluctuations effects visual comfort of healthcare professionals in nursing homes.

[Paper_ID521](#)

ENVIRONMENTAL ASSESSMENT OF INDOOR ENVIRONMENTAL QUALITY IN NEW BUILDING – CASE STUDY

Assessment System; Environmental Assessment; Indoor Environmental Quality

Vilcekova, Ms. , Kridlová Burdová, E

Integrated building design should take into account environmental, social and economic dimensions of sustainability. These three dimensions of sustainability are incorporated in systems of building sustainability assessment. An important trend is the increasing number of tools world-wide that aimed at making comprehensive environmental assessment of buildings and provides rating for simplified communication. The building environmental assessment system (BEAS) has been developed in Slovakia as well through the last years. The main fields and indicators of BEAS are proposed on the base of available information analysis from particular fields and also on the base of our experimental experiences. The proposed indicators respect Slovak standards and rules. The objective of this paper is evaluation of building in the field of Indoor Environmental Quality (IEQ) by system BEAS and also by worldwide preferred system LEED. LEED as green building certification program recognizes best-in-class building strategies and practices. The main goal is to analyse and compare the achieved results to determine the suitability for use of various building sustainability assessment systems in the given country.

[Paper_ID522](#)

EVALUATION OF THERMAL COMFORT BASED ON EEG AND PHYSIOLOGICAL REACTION BY SUBJECT EXPERIMENTS

EEG; PMV; subject experiment

Tanishita, T. , Kitagawa, K , Matsumoto, M ,



In this paper, we have attempted to evaluate indoor thermal comfort based on EEG and human physiological reaction when the thermal environment evaluated by PMV 0 is comfortable in practical under the same comfort level formed by any combination of 6 elements, air temperature, humidity, air velocity, radiation, clo value and metabolic rate. Subject experiments were done under three thermal conditions of PMV 0 by controlling air temperature, relative humidity, air velocity and clo value in an artificial climate chamber. Subjects were asked to sit on the chair for 40 minutes including a 10 minute task period. The body temperature, EEG, heart rate, and salivary amylase were measured.

Every 5 minutes, a questionnaire about subjects' thermal sensation was recorded.

As a result, the average EEG data among some subjects have a few significant differences and correlations between the other thermal indexes. On the other hand, individual analysis, there are some significant differences of the EEG data between each case, and the correlations of EEG data and thermal sensation are shown. Thus, it is not to be denied that even in the same PMV condition, EEG or thermal sensation show different reactions by the different combinations of environmental and individual factors.

[Paper_ID523](#)

INSUALTE PROJECT – BUILDING ASSESSMENT AS A PART OF ASSESSMENT IMPACTS OF ENERGY EFFICIENCY ON INDOOR ENVIRONMENTAL QUALITY AND HEALTH

Buildings; Energy efficiency; IEQ

Leivo, V. , Kiviste, M. , Aaltonen, A. , Du, L. , Prasauskas, T. , Martuzevicius, D. , Haverinen-Shaughnessy, U. ,

INSULAtE project focuses on demonstrating impacts of improving energy efficiency (EE) on indoor environmental quality (IEQ) and health, and developing a common assessment protocol. The protocol consists of three parts: building, IEQ, and health assessment. Case studies conducted in multi-family buildings in Finland and Lithuania before and after energy retrofit aim to examine which measurements are most applicable to assess IEQ impact of energy retrofit. Building related assessment in case study buildings has included: reviewing available blueprints and energy certificates, 2-month continuous measurement of T and RH in the occupied zone (average) and coldest spot of the envelope surface, one-time measurement of air flows from ventilation inlets, measurement of air pressure difference between indoor and outdoor and staircase, and air tightness of the envelope (in some buildings). Measurement of the indoor and outdoor T and RH in the occupied zone reflect thermal comfort, while conditions at the coldest spot indicate thermal resistance and airtightness of the envelope and can also indicate risk for excess moisture and mold growth. Thermal index, which is estimated based on inner surface temperature, average indoor T, and outdoor T, is a good indicator of thermal conductivity and air leakages through the envelope.

[Paper_ID524](#)

DISCUSSION ON THE PERFORMANCE EVALUATION OF AIR CLEANING DEVICES- BASED ON THE CHINA GB/T 18801 STANDARD

Air cleaners; Performance evaluation; Standardization

KE, A. , Zhang, Z Q , Graff, T , Kelly, D



With the deterioration of air quality, air cleaning devices are becoming more and more important a part of healthy buildings, no matter whether they are in-home air purifiers or customized air purification modules installed in the ventilation duct. China GB/T 18801 is a continuously upgraded standard that covers the requirements and testing protocols of above mentioned devices.

As gas-phase indoor air pollution is one critical concern from the public, especially in China, an important update of GB/T 18801 is at assessing effectiveness of in-home gas-phase air cleaning devices. In this paper, some discussion points will be addressed in assessing the gas-phase air cleaning performance of air cleaners.

[Paper ID525](#)

RENOVATION OF A SINGLE FAMILY HOUSE IN A SOCIAL HOUSING GARDEN CITY IN BRUSSELS AS PRIVATE-PUBLIC COLLABORATION: AMBITIOUS TARGETS FOR ENERGY, INDOOR CLIMATE AND POST-OCCUPANCY MONITORING

Dwellings; Indoor climate; Renovation

Foldbjerg, P. , Geuens, J , Pauquay, S ,

RenovActive is a renovation project in Brussels based on the concept of Climate Renovation that implies achieving an excellent indoor climate as well as energy performance. The house is part of a social housing association, and is renovated within the financial frame for social housing, and renovated using standard solutions and products to facilitate future replications of the result. The different renovation scenarios have been analysed with dynamic simulation and daylight analyses, and the Active House specification has been used to evaluate the scenarios. The house will be equipped with balanced mechanical ventilation for winter use, and demand-controlled natural ventilation. When building works have been completed, the house will be occupied by a family, and physical measurements as well as social scientific enquiries will be carried out.

[Paper ID526](#)

VAPOR AS A CARRIER OF TOXICITY IN A HEALTH TROUBLED BUILDING

Airborne toxicity; Mycotoxin exudates; Penicillium expansum

Salo, M.J. , Andersson, M.A , Mikkola, R , Kredics, L , Viljanen, M , Salkinoja-Salonen, M.S



"*Penicillium expansum*" was identified as a major contaminant in indoor air, settled dust and materials of several buildings connected to indoor air related health complaints. This fungus emitted large quantities of exudates when cultivated on laboratory media. The exudates proved toxic towards four different mammalian test cells up to 10000 fold dilution. Toxins identified by LC-MS/MS were communesins and chaetoglobosin. Air dispersal of the toxic exudates was investigated with an experimental set-up where natural convection was generated by temperature gradient. It was found that the exudate with the contained toxins became airborne transported from the warmer surface to the colder surface. The results thus demonstrate transportation of microbially produced toxic substances across the air space. The role of liquid emissions from indoor molds represents a novel mechanism for human exposure in mold contaminated buildings. In this paper we report that vapor condensed from the indoor air of building affected with molds "*Aspergillus versicolor*, *Aspergillus calidoustus*" and "*Penicillium expansum*" contained substances that were acutely toxic when exposed to mammalian cells "in vitro". The results encourage further study of condensed indoor water vapor as a tool to assess the presence of airborne substances with possible adverse health effects.

[Paper ID527](#)

HEALTH ASSESSMENT ASPECT ON ENERGY EFFICIENCY RENOVATIONS

Energy efficiency; Health questionnaire; Indoor environmental quality

Turunen, M. , Pekkonen, M. , Prasauskas, T. , Martuzevicius, D. , Leivo, V. , Aaltonen, A. , Haverinen-Shaughnessy, U. ,

INSULAtE-project aims to demonstrate how improving energy efficiency (EE) in buildings impacts on indoor environmental quality (IEQ) and occupant health. In the first phase, a total of about 20 multifamily buildings from both Finland and Lithuania were included. Measurement data on IEQ parameters and questionnaire data on occupant health were collected from approximately 5 apartments per building both before and after renovation. Questionnaire data includes information concerning occupant perceived housing satisfaction, health and wellbeing, and occupant behaviour. One adult per apartment was asked to fill in a questionnaire, both before and after renovation.

The preliminary pre-renovation questionnaire data shows that some 76% of the respondents in Finland and 59% in Lithuania were satisfied or fairly satisfied with IAQ. Most of the respondents (82%) in Lithuania reported relative low indoor heating temperature (=20 °C) whereas in Finland, 28% households reported heating temperature =22 °C. Regarding well-being and health, the occupants in Finland had reported more daily/almost daily general symptoms, and both upper and lower respiratory tract infections during the past 12 months than the occupants in Lithuania. Furthermore, some 36% of the occupants in Finland and 24% in Lithuania thought their health symptoms were associated with home environment.

[Paper ID528](#)

RESULTS FROM POST-OCCUPANCY EVALUATION IN FOUR SINGLE-FAMILY HOUSES

Health and Sleep Quality; Interior Environment; Post-Occupancy Evaluation

Christoffersen, JEC. , Foldbjerg, PEF



This paper describes the Post-Occupancy Evaluation (POE) of five families living, for one year, in the Model Home 2020. The houses are located in Germany, Austria, France and UK. The survey is carried out seasonally during the test year the family lives in the house allowing to capture and explore variation on a seasonal basis. The questionnaire is focusing on energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability. The results give an indication of what the families think of the houses, of its interior environment, and how the environment is experienced etc. In general, the families indicate high satisfaction with the indoor environment, better health, fewer sick days and improved sleep quality, that their expectations often are fulfilled, that house automation is acceptable, and being able to follow energy consumption and production increase awareness of their behavioral influence.

[Paper ID529](#)

NEW DEVELOPMENTS IN THE ASSESSMENT OF HAZARDOUS SUBSTANCES FROM PRODUCTS USED INDOORS

product emissions; secondary reaction products; source control

Lor, ML. , Maes, FM , Stranger, MS , Spruyt, MS , Lazarov, BL , Poelmans, DP , Swinnen, RS , Goelen, EG

Increasing knowledge about the close relationship between indoor air quality and human health has resulted in more and more concern among all stakeholders about healthy buildings and also healthy products used indoors. In Belgium a new Royal Decree concerning VOC emissions from construction products came into force in January 2015. This legislation is in line with current European harmonization efforts such as the new documentation requirements of VOC products emissions in CE marking (CPR).

Recently the research and normalisation activities are shifting towards other product groups such as consumer and personal care products as well as the assessment of health relevant secondary reaction products (SRPs)

[Paper ID530](#)

NEW DEVELOPMENTS OF THE EMISSION CLASSIFICATION OF BUILDING MATERIALS IN FINLAND

Building material; fixture; material emission

Sariola, LS. , SÄTERI, JS , JÄRNSTRÖM, HJ ,



The Finnish Society of Indoor Air Quality and Climate (FiSIAQ) introduced twenty years ago in 1995 a Classification of Indoor Climate, Construction Cleanliness, and Finishing Materials. The third edition will be published in 2016. Based on the criteria set in the classifications, The Building Information Foundation RTS started the M1-labelling of building products in 1996, named Emission Classification of Building Materials and Cleanliness Classification of Air-handling Components.

High indoor air quality is recognized as an important issue of both national health and economy in Finland. Companies have developed low-emitting building materials, fixtures, furniture and HVAC devices to meet these requirements. There have been clear improvements also in construction technology and the use of buildings. The new specific requirements and criteria of the classification of building materials, fixtures and furniture, including testing protocol changes and sample testing results will be presented.

The classification of building materials and HVAC devices follows the changes, developments and needs of the market, there are newly launched products classified continuously. Several measures have been taken to achieve and maintain healthy and comfortable IAQ in homes, offices and other buildings.

[Paper ID531](#)

FULLY AUTOMATED, ON-LINE MICRO-SCALE CHAMBER METHOD FOR DETERMINATION OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM BUILDING PRODUCTS

emission; micro-scale chamber; VOC

Nie, Y, N. , Mayer, I.

Automated dynamic headspace measurements using micro-scale chambers (DHS-L) were evaluated as alternative to standard emission test chamber measurements following ISO 16000-6/-9 for determination of VOC emission properties of building products. DHS-L allows an automated sampling from micro-scale chambers using Tenax TA sorbent tubes followed by an automated VOC characterization by thermal desorption and GC-MS. Parquet varnish samples were assed with both techniques. Chromatographs showed similar behavior for number, retention time and peak shape of individual VOC. Both methods allowed the identification of all relevant VOC in the samples, mostly aldehydes and organic acids. For some compounds similar values for the area specific emission rates after 3 and 28 days after application of the varnish were recorded. The results proofed the potential of DHS-L for an efficient screening method to complement ISO 16000-9 emission test chamber experiments. Additional efforts has to be spend in method validation and further improvement of the DHS-L methodology to reduce the test duration for 28 days values, which are relevant in ISO 16000-9 testing.

[Paper ID532](#)

IAQ DETERMINANTS IN A LOW ENERGY SCHOOL THROUGH TIME-RESOLVED MEASUREMENTS: OUTDOOR AND INDOOR CONTRIBUTIONS TO THE INDOOR CHEMISTRY.

field campaign; low energy building; time resolved measurements

Schoemaecker, C. , Blocquet, M , Rizk, M , Ward, M , Guglielmino, M , Liaud, C , Mendez, M , Verrielle, M , Dusanter, S , Hanoune, B. , Hanoune, B. , Petitprez, D , Le Calvé, S , Blond, N , Hauglustaine, D , Blondeau, P. , Locoge, N ,



Pollutant concentrations in the indoor environment are controlled by numerous physical and chemical processes. In energy-efficient buildings, modern materials are used and ventilation is controlled. These specific conditions based on energy saving considerations can have a strong impact on Indoor Air Quality (IAQ). The MERMAID project aims at characterizing the IAQ in such buildings and studying the contribution of the different processes that drive indoor pollutant concentration levels.

After preliminary passive sampling measurements in 10 energy efficient school buildings, two intensive measurement campaigns were organized in one of them. A detailed indoor air model has also been developed.

This paper reports the results of the first intensive campaign, carried out during spring 2014, providing time-resolved (~1 min) information on indoor and outdoor physical and chemical parameters (ozone, nitrogen oxides, volatile organic compounds, radicals, solar radiance). Rapid changes of air quality in the classroom, depending on the ventilation conditions, were monitored. When the ventilation is active, the concentration of the indoor-generated pollutants decreases rapidly (tens of minutes), whilst the pollutants generated outdoors, such as ozone, are simultaneously introduced with only minor abatement through the ventilation system.

[Paper ID533](#)

IMPACT OF PERSONALIZED VENTILATION COMBINED WITH CHILLED CEILING ON SBS SYMPTOMS INTENSITY

personalized ventilation; radiant cooling; Sick Building Syndrome

Lipczynska, A., Kaczmarczyk, JK, Melikov, AM,

This paper presents the influence of the environment created by personalized ventilation (PV) combined with the chilled ceiling (CC) on Sick Building Syndrome (SBS) symptoms intensity reported by occupants. Twenty-four human subjects participated in four 3-hour experiments in climate chamber. Performance of PV combined with chilled ceiling system (CCPV) and mixing ventilation (MV) combined with chilled ceiling (CCMV) was studied at room air temperature of 26°C and 28°C. Supply air temperature (by PV and MV) was 3 K lower than room air temperature. During sessions with PV subjects were provided with individual control of supplied personalized air flow rate and its' direction. After 45 min of acclimatization subjects performed sedentary tasks at workstations with computers and walking exercises. Subjective responses were collected through questionnaires. Subjects reported on intensity of SBS symptoms 6 times throughout each experiment. Results reveal building up of symptoms intensity in time at all studied cases. PV decreased intensity of most of analysed symptoms at 28°C compared to MV. The ability to concentrate and fatigue was also improved at 26°C with PV.

[Paper ID534](#)

THE VALUE OF COMFORT AND ENERGY IN A RENOVATION, A CASE STUDY

Daylight; Energy efficiency; Visual comfort

Khademagha, P.,



In the process towards a more sustainable built environment, the campus of the Technical University in Eindhoven, the Netherlands, is going through a reconstruction phase in which outdated buildings with reduced functionality are upgraded. One of the buildings, the so-called Matrix building, has a low occupancy rate and insufficient daylight performance. This study shows a smart renovation plan for the building including improved user comfort and health, enhanced energy efficiency, and possible cost saving opportunities.

Radiance lighting simulation software is used to compare different design scenarios. Daylight performance and visual comfort of the occupants, energy performance, and layout configuration were evaluated and compared for every design scenario.

Cross referencing all design scenarios to the current situation, highlights the advantages of the design scenario in which four centralized atriums, in two sizes, with fully glazed façades are distributed over the floor plan. Implementing atriums introduced more day-lit spaces in the building with a view to the outside which resulted in enhanced space usability. Additionally, not only daylight performance and visual comfort is increased, but also dependency on artificial lighting is decreased.

[Paper_ID535](#)

VENTILATION RATES IN NATURALLY VENTILATED ITALIAN CLASSROOMS THROUGH PRESSURIZATION TEST

air change rate; pressurization test; schools

Stabile, L.S. , Frattolillo, A.F. , Dell'Isola, M.D. , Massimo, A.M. , Russi, A.R. ,

In the present paper the results of an experimental analysis aimed to evaluate the ventilation rates in Italian classrooms are reported. Measurements were performed in 16 classrooms of 7 different public primary schools located in the Central Italy. Schools with a natural ventilation system were considered. Ventilation rates were evaluated through the pressurization method using a blower-door tool. Both pressurization and depressurization tests were performed. The study confirmed that the classrooms under investigation cannot be properly ventilated only relying on natural ventilation systems. In fact, an average natural air change rate equal to 0.12 h⁻¹ was measured. This value is only the 5% of the minimum ventilation required by the European standards.

[Paper_ID536](#)

INFLUENCE OF RESIDENTIAL ENVIRONMENT ON RESIDENTS' HEALTH PROMOTION

Questionnaire survey; Residential environment; Residents' health status

Kawakubo, S. , Ikaga, T , Murakami, S , Hoshi, T , Ando, S ,



Housing plays a critical role in human life, and the establishment of a residential environment that promotes the health of its residents is a pressing issue. Numerous studies on housing have been previously conducted in this social context; however, only a few have considered the comprehensive health risk due to the overall residential environment. In the present study, therefore, a nationwide questionnaire survey was conducted to examine the residential environment of detached houses and its impact on residents' health status. A tool used in the Comprehensive Assessment System for Built Environment Efficiency (CASBEE), namely, the CASBEE Health Checklist, was distributed to various detached houses throughout Japan to assess the overall residential environment. The checklist covers residential environmental elements concerning thermal environment, acoustic environment, light environment, hygiene, safety, and security. Respondents were asked about their current health status and that of family members. The questionnaire results were cross-tabulated, and odds ratios and significance probabilities were calculated. Results showed that the overall residential environment was likely an important determinant of health and was associated with prevalence of certain chronic diseases among residents. Odds ratios tended to be less than 1.0, indicating that low disease prevalence was associated with a good residential environment.

[Paper ID537](#)

ASSESSING THE NEAR-PATIENT INFECTION RISK IN ISOLATION ROOMS

bacteriological tests; gas tracer; Isolation rooms

Beato Arribas, B., McDonagh, Dr.A., Noakes, Dr. C., Sleight, Dr. P.A., McDonagh, Dr.A.,

Isolation rooms designed for protection against airborne infection have been designed based on a certain number of ACH (air changes per hour) and a differential pressure with adjacent spaces. In the validation process of an isolation room, gas tracer is generally used to simulate airborne infection.

The experiments carried out focused on studying the risk of infection when the recipient is very close to the source (i.e. hospital staff working very close to an infectious patient) and studying how gas tracer tests compare to bacteriological tests.

The results show good comparison between the behaviour of gas tracer and bacteria in the same room and the bed in different positions, thus validating the use of a tracer gas to represent the airborne behaviour of bioaerosols.

[Paper ID538](#)

ENERGY EFFICIENT MODERNIZATION OF HOUSING STOCK: DEMONSTRATION OF IMPACTS ON INDOOR ENVIRONMENTAL QUALITY IN NORTHERN EUROPE

Exposure assessment; Indoor environmental quality; Residential buildings

Martuzevicius, D., Prasauskas, T., Du, L., Taubel, M., Leivo, V., Kiviste, M., Haverinen-Shaughnessy, U.,



Energy efficient (EE) building renovation is mostly based on economic aspects – performing cost-effective renovation actions assuming further savings in energy costs, without taking into account possible changes in indoor environmental quality (IEQ) conditions. The World Health Organization resolution on environment and health has called for policies to protect public health from the impacts of major environment-related hazards such as those arising from climate change and housing (WHO, 2004). Therefore, a more comprehensive analysis on IEQ is essential. It is obvious that effective assessment of interactions between climate change, building environment, EE, and public health demands move from a traditional disciplinary approach to integrated knowledge from all sectors involved. However, complex research studies covering all these factors (EE, environment, and health) are essential not only on a national level but worldwide as well.

In Finland and Lithuania (representing the region of Northern Europe), the renovation programs for multifamily apartment buildings are gaining their momentum. INSULatE project focuses on assessment of national policies and programs targeting to improve EE of the European housing stock, at the same time developing a comprehensive protocol for assessment of the impacts of EE on IEQ and health.

[Paper_ID539](#)

INDOOR AIR QUALITY IMPROVEMENT BY PHOTOCATALYTIC OXIDATION

Coating; Photocatalysis; Titanium dioxide

Lorencik, S. , Yu, Q.L. , Brouwers, H.J.H. ,

Present study aimed to analyze the potential of a previously developed photocatalytic water-based top-coatings (PCO coatings) applied on wallpaper for the indoor air quality improvement. The effect of the amount of layers (L1-3) of the PCO coating and/or nano-silica addition into the formulation of the PCO coating on the photocatalytic efficiency was evaluated.

The photocatalytic efficiency was assessed on the lab scale by the degradation of inorganic pollutant - nitric oxide (NO). Tested samples were embedded in the plug-flow experimental set-up (corresponding to the ISO 22197-1), and tested under visible light irradiation, flow rate of 1.5 L/min and 500 ppb of NO. These modified conditions were applied in order to simulate closer indoor conditions. Ultraviolet (UV) pre-treatment method was applied prior to the PCO assessment in order to promote the PCO efficiency.

All coatings exhibited high PCO efficiencies for NO_x degradation under applied experimental conditions. The PCO efficiency was clearly positively affected by the nano-silica modification and in to some extent by the number of layers of the coating. The best performing coatings, able to degrade 69% of NO_x, were those modified with nano-silica and applied in two layers.

[Paper_ID540](#)

REVOLUTION/EVOLUTION—DNA SEQUENCING TO IDENTIFY INDOOR MICROORGANISMS

bioinformatics; indoor microbiome; metagenomics

Peccia, JP. ,



Since the year 2007, biology has been revolutionized by new technologies that allow for sequencing DNA rapidly and inexpensively. Using existing taxonomic and phylogenetic frameworks, the indoor microbiology field has thus far leveraged next generation DNA sequencing to build catalogues of indoor microorganisms, defined relationships between building variables and microbial communities, and has made limited strides in understanding how indoor bacteria and fungi impact human health. This talk will introduce the "revolution" of next generation DNA sequencing, and provide perspective on the "evolution" of this technique required to realize its full potential in indoor microbiology research and applications.

[Paper ID541](#)

PM2,5 MEASUREMENT PROTOCOL FOR OFFICES

Offices; Protocol; Yearly average PM2,5

Jacobs, P. , Voogt, M

People are more than 80% of their time indoors. However, in contrast to ambient air, no (legal) limits for indoor particulate matter exist. This paper describes a measurement protocol to determine the yearly averaged indoor PM2.5 concentration and gives reference values for five quality classes: 2,5 µg/m³ (A+), 10 µg/m³; (A: WHO annual advisory value), 17,5 µg/m³ (B), 25 µg/m³ (C: EU limit value) and above (D). The indoor PM2.5 concentration is measured with an optical particle counter. The hourly outdoor concentration is derived from an outdoor station of an air quality monitoring network. This allows to determine an estimate for the infiltration coefficient and the indoor PM2.5 sources based on one week of data. The infiltration coefficient is a characteristic parameter for the efficiency of the air filters and the air tightness of the building. Based on these parameters and the yearly averaged ambient concentration a good approximation of the yearly averaged indoor PM2.5 concentration can be derived. Three case studies in offices are discussed: 4,4 (F7 filter), 5,8 (F7 filter) and 1 µg/m³ (F6 filter). The results clearly show that not only the filter quality but also the building air tightness is a very important parameter.

[Paper ID542](#)

EVALUATING THE CONSEQUENCES OF RETROFITTING RESIDENTIAL MULTI-FAMILY BUILDINGS ON INDOOR ENVIRONMENTAL QUALITY, COMFORT, HEALTH AND USER SATISFACTION

Comfort; Health; Indoor environmental quality

Kluzenaar, Y. , Jong, P de, Cornelissen, HJM , Vliet, MRA van, ,



INTRODUCTION Within the European project RETROKIT a systemic approach is being developed for retrofitting existing multi-family residential buildings. Modular combination of (semi-) prefabricated technological solutions is demonstrated in three case studies. This part of the study aims to evaluate the consequences of the retrofit process on indoor environmental quality (IEQ) and user satisfaction.

METHODS In three case studies, in different climate regions in Europe, measurements will be performed for key indoor environmental parameters "before" and "after" retrofit.

Simultaneously, user information will be collected face to face, including perceived IEQ, comfort, health, quality of living, and other aspects of user satisfaction. This data will be analyzed to evaluate the consequences of the retrofitting process on IEQ (including air quality, noise, lighting, thermal aspects), perceived indoor environmental quality, comfort, health and quality of living.

RESULTS AND DISCUSSION Building on previous large European projects, a protocol has been developed for the measurement campaigns, which are planned to start in the winter of 2014/2015. Results of the first measurement campaigns are expected early spring 2015.

CONCLUSION The results from this study will provide valuable insights and recommendations for improvement of the retrofitting process with respect to indoor environment, comfort, health and user satisfaction.

[Paper ID543](#)

ASSESSMENT TOOL FOR BUILDING MATERIALS

assessment tool; building material; sustainability

Lima Vasconcelos, SLV. ,

This paper focuses on the selection of building materials in the planning process and the challenges of an interdisciplinary design. There have been insufficient evaluation methods that are at the same time based on a holistic analysis and user-friendliness. For this reason, a new approach is presented for an assessment tool used in the author's PhD work, which transformed the complex data in an easy-to-read result without losing any content. As an example, we analyse and compare three different interior plasters: clay, stucco and lime to a reference material the cement plaster. For this example we choose a specific location, an office building in Berlin, where the materials will hypothetically be installed. The results will show the strengths and weaknesses of each product and offer an easy reading graphic design for an easy interpretation. The discussion leaves to the importance of the raw data quality and the possibility to use this tool flexibly. The conclusion resumes the potential of this assessment tool, leading designers to a better planning practice.

[Paper ID544](#)

DEVELOPMENT OF AN ASSESSMENT PROTOCOL: THE IMPACT OF ENERGY RETROFITS ON INDOOR ENVIRONMENTAL QUALITY AND PUBLIC HEALTH IN THE EXISTING BUILDING STOCK

Assessment protocol; Indoor environmental quality; Retrofits

Du, L. , Leivo, V. , Martuzevicius, D. , Turunen, M. , Prasauskas, T. , Kivistie, M. , Haverinen-Shaughnessy, U. ,



INSULAtE project (www.insulateproject.eu) aims to develop and test a comprehensive protocol for assessment of indoor environmental quality (IEQ) that could be used in connection with energy audits and retrofits. The protocol includes building-related assessment, exposure assessment, and health assessment. Field studies targeted existing multi-family buildings undergoing retrofits. A total of 46 case-study buildings from Finland and 20 from Lithuania were recruited. Building information, retrofit activities, as well as data on IEQ parameters were collected from each building. In addition, questionnaire data regarding housing quality and health were collected to accompany the assessment. The baseline results demonstrated a general agreement between building characteristics, measured IEQ, and occupants' responses. Substantial differences in indoor environmental conditions were observed between the countries, likely due to building characteristics, type of ventilation, occupant behaviors, socio-economic status and other baseline conditions, as well as retrofit activities. The effects of retrofit based on post-retrofit data (preliminary results) seemed to be different between countries, showing both positive and negative changes. These results help to identify possible IEQ indicators, and develop, test, and refine the protocol. Future analyses will clarify the impact of retrofit on IEQ and occupants' health, which will also guide the finalization of the assessment protocol.

[Paper_ID545](#)

AN ALTERNATIVE VENTILATION SYSTEM FOR OPERATING THEATRES: A FULL-SCALE EXPERIMENTAL STUDY ON THE PERFORMANCE OF A LOCAL VENTILATION SYSTEM

Air quality; Relative particle concentration; Surgical site infection

Visser, IM. , Loogman, J., Loomans, M.G.L.C. , Kort, H.S.M. , Sanden, N.P.M. van der, Noor, R.J.R. , Burgmeijer, E.R.T. , Wieren, P. van, ,

Surgical site infections occurred in 2.9% of the operations in conventionally ventilated operating theaters in The Netherlands. New performance-based Dutch guidelines offer the opportunity to apply alternative systems. Therefore, a local ventilation system was studied where only the wound area and the instrument tables are ventilated. The clean air supply around the wound area was combined with a blanket which lies over the patient during the operation. Two configurations were studied: HEPA-filtered air supply around and parallel to the wound area (configuration 1) and from the top surface of the blanket, perpendicular to the wound area (configuration 2). Similar approaches were applied to the instrument tables. The performance was tested in a detailed full-scale mock-up of an operating theatre. Relative particle concentrations were determined according to Dutch guidelines.

In the centre of the wound area, relative particle concentrations varied between 1% and 10% for both configurations. The variances were probably caused due to irregular contamination in the periphery and imperfections of the prototypes. The results of the instrument tables were more uniform and resulted in relative particle concentrations of approximately 1% (configuration 1) and 0% (configuration 2) at the center of the tabletop. Although both configurations gave a reduced particle concentration in the wound area and on the instrument table compared to the contaminated periphery, only configuration 2 of the instrument table performed conform the VCCN guideline.

[Paper_ID546](#)

ON ASSOCIATIONS BETWEEN EXPOSURE TO HOUSEHOLD CHEMICAL PRODUCTS AND ASTHMA AND ALLERGIES AMONG CHILDREN IN TIANJIN, CHINA



Chemical products; Children; Health

Hou, J. , Sun, YX , Kong, XR , Wang, P , Zhang, QN , Sundell, J

More and more chemical products are used in homes with the development of a modern society. In order to investigate exposure to chemical products in homes and its potential effects on children's health, a study on home environment and children's asthma and allergy is launched at Tianjin, China. This is a cross-sectional study. Questionnaires were used to survey the exposure to detergents, furniture polish and insect spray, as well as health outcomes (such as asthma, rhinitis, eczema and pneumonia) of the occupants. 6725 parents of children (0-8 years) reported their use of household chemical products and children's health outcomes. 4.8% children have been diagnosed with asthma, and 29.3% children have been diagnosed with pneumonia in Tianjin. The association between use of detergents in bath or washing room and allergic symptoms among children was seemingly strong (AOR: 2.24, 95% CI: 1.33-3.78). The results indicated that exposure to household chemical products may have negative effects on occupants health.

[Paper_ID547](#)

LONG TERM PERFORMANCE OF PARTICULATE AIR-FILTER IN AN OFFICE ENVIRONMENT

efficiency of a filter; ionizer; Particulate air filter

Afshari, ALA. , Iqbal, AHI , Bergsøe, NCB ,

The present article is based on initial findings of an ongoing study. The objective of present study is to analyse the long term performance of an air particulate filter with and without ionizer. To study the performance of the air filters, a test rig was built in the Danish Building Research Institute - Copenhagen. Two parameters, pressure drop across the filter and ultrafine filtration efficiency of the filter are analysed for describing the performance of the filter. In the preliminary findings it was found that the ultrafine particle filtration efficiency of the air filter was 60%. The efficiency decreased with time. The pressure drop across the filter did not decrease significantly. When the same type of filter was used in with air ionizer, the efficiency at the beginning was 90% but it reduced to 60% after 1500 running hours. Hence it is concluded that the filtration efficiency does not increase much by the introduction of the ionizer on long term basis.

[Paper_ID548](#)

BEDROOM ENVIRONMENTAL CONDITIONS IN AIRTIGHT MECHANICALLY VENTILATED DWELLINGS

Bedroom ventilation; Carbon dioxide; Indoor air quality

McGill, G.M. , Oyedele, L.O , Keeffe, G.K , Mc Allister, K.M , Sharpe, T ,



The indoor environmental quality in energy efficient dwellings is a significantly important yet under-researched area, particularly in bedrooms where people spend much of their time and adaptive ventilation behaviour is restricted. This paper presents the results of an indoor environmental assessment of four new build energy efficient social housing projects; focusing specifically on bedroom conditions. The study involved monitoring of bedroom temperature, relative humidity and carbon dioxide levels during summer and winter seasons, the use of an occupant diary to record conditions during the monitoring period in conjunction with occupant interviews to examine perception of the indoor environment and occupant behaviour in the dwellings. The findings indicate significant issues with night time ventilation; which suggests inadequate ventilation strategies in the case study dwellings. In addition, temperature and relative humidity levels regularly exceeded recommended levels for comfort and health. The findings demonstrate a potential negative effect of contemporary energy efficient housing design strategies on bedroom environmental conditions; highlighting a possible risk to occupant health and wellbeing.

[Paper ID549](#)

INSUFFICIENT AIR SUPPLY RATES IN NEW BUILT APARTMENTS WITH ENERGY EFFICIENT VENTILATION – INCLUDING ASPECTS OF HUMAN PERCEPTION AND BEHAVIOR

Air supply rates; apartments; user interaction

Nordquist, BN. , Fransson, VF

A well-functioning ventilation system is significant in achieving a healthy indoor environment. The air supply rate is one of the important factors in reducing the pollutant levels indoors. A study of the indoor environment has been made in new built apartments with modern energy-efficient mechanical supply and exhaust ventilation systems. Several parameters have been measured including the air supply rates, and the performance of the ventilation system. Interviews with the residents have also been made. This paper focuses on the air supply rates with the objective of examining these.

The results show that the air supply rates are not fulfilling the building regulations in several apartments. Several reasons for the insufficient air supply rates have been identified; not only has the performance of the ventilation system itself but also the resident/user interaction with the ventilation system negatively impacted on the air supply rates. The experience of the residents including perception of noise has also lead to reduced air supply rates.

The results illustrate the importance of including the interaction of the residents. Suggestions are made on factors important to address and observe both when designing the ventilation system and during operation if a satisfactory indoor environment is to be achieved.

[Paper ID550](#)

IMPROVING SCHOOL INDOOR AIR QUALITY

IAQ enhancement; Source control; source identification

Stranger, M. , Constandt, K.C. , Staelens, J.S. , Maes, F.M. , Lazarov, B.L. , Lor, M.L. , Goelen, E.G. ,



Since children spend a considerable part of the day at school, classroom indoor air quality (IAQ) is a major contributor to their personal exposure. The geographical location of a school, outdoor sources (industry or traffic), the building envelope (including the ventilation system), as well as indoor decorations and used consumer products, all contribute to classroom indoor air quality (IAQ). Because of the potential impact of a poor IAQ on children's health, suitable measures to assess and reduce classroom indoor air pollutants (IAP) in Belgian schools are taken. This work presents the outcomes of 5 years IAQ assessment studies in schools.

[Paper ID551](#)

INDEX OF INDOOR AIRBORNE FUNGAL SPORES POLLUTION IN BRUSSELS HABITAT

Green Ambulance; Habitat; Indoor Airborne Moulds

CHASSEUR, CC. , Bladt, . , Wanlin, . ,

The abnormal presence of any mould in any location within a building, presents a health risk, especially for young children and asthmatic people. In Brussels, the Regional Unit for Indoor Pollution Intervention assists the general practitioner in his diagnosis when there is a suspected link between his patients health and his home. For moulds, the most evident and easiest evaluation tool consists in a visual inspection. But hidden contaminations are often present and require air sampling methods. An index of indoor pollution with airborne fungal spores has been developed on the basis of over 1600 surveys in dwellings. This index is based on several airborne concentrations percentiles obtained for some specific moulds. In Brussels, the best represented airborne moulds in the visited dwellings were "Penicilium spp., Aspergillus versicolor" and "Cladosporium sphaerospermum". These 3 taxa are the basis of the index. But when other specific toxigenic moulds are present, they are taken into account.

In conclusion, this index helps to decide when a measured airborne fungal concentration may be considered as abnormal. The index provides additional information in order to improve the environmental analyses, and is particularly useful when the presence of moulds is suspected but when they remain invisible.

[Paper ID552](#)

DETERMINATION OF RADON EXHALATION FROM BUILDING MATERIALS IN DYNAMICALLY OPERATED TEST CHAMBERS BY USE OF COMMERCIALY AVAILABLE MEASURING DEVICES

Building material; Radon exhalation; VOC emission test chamber

Hofmann, MH. , Richter, MR , Jann, OJ ,



The inhalation of radon decay products is the leading cause of lung cancer apart from tobacco smoking. Due to low air change rates, the radon exhalation from building materials can have an important contribution to the indoor radon concentration. In a research project financed by the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety a practical, reliable and easily applicable test procedure for the determination of radon exhalation from building materials should be developed. In this contribution to the conference first results of this study are presented, focused on the reliable measurement of background concentration and the selection of suitable radon monitors.

Measurements were carried out with four models of commercially available radon measuring devices which were connected to dynamically operated emission test chambers.

A prerequisite for the use of dynamically operated emission test chambers in combination with suitable radon test devices for the measurement of radon exhalation from building materials under realistic indoor conditions is fulfilled. As radon concentration in the test chambers might be low, measurement devices have to be selected in regard to their sensitivity. Furthermore, detailed investigations on the blank value of the air supply system and the device background level are essential.

[Paper ID553](#)

THERMAL COMFORT OF DISPLACEMENT VENTILATION IN ENVIRONMENTS WITH DIFFERENT TEMPERATURE GRADIENTS

displacement ventilation; indoor climate; thermal comfort

Möhlenkamp, M., Schmidt, M., Wick, A., Gores, I., Müller, D.,

The evaluation and prediction of local thermal comfort is becoming increasingly important. Nevertheless the most common complaints about heating, ventilation and air conditioning systems are about the temperature being too cold or too hot.

A highly modular test chamber was built in order to evaluate the thermal comfort in indoor environments by test persons. The cube can be mapped to different situations with variable surface temperatures and a variable air distribution system. It has a floor area of 2 m x 2 m and a height of 2.5 m. Three of the surrounding side walls are divided into four surface segments. Each surface segment can be set to a temperature between 10 °C and 45 °C.

Test trails are used to investigate different temperature gradients between ankle (0.1 m) and head (1.1 m) of displacement ventilation. Vertical temperature differences with a gradient of $\Delta T/\Delta y = 1 \text{ K/m}$, $\Delta T/\Delta y = 4.5 \text{ K/m}$, $\Delta T/\Delta y = 6 \text{ K/m}$, $\Delta T/\Delta y = 8 \text{ K/m}$ and $\Delta T/\Delta y = 12 \text{ K/m}$ are tested. The results are even better than the predicted thermal comfort in literature data from ASHRAE Standard 55. The percentage of dissatisfied persons rises with higher vertical air temperature difference nearly linear.

[Paper ID554](#)

QUANTIFYING THE IMPACT OF ENVIRONMENTAL PARAMETERS ON THE FORMATION OF SECONDARY REACTION PRODUCTS FROM TERPENE/OZONE REACTIVE CHEMISTRY UNDER CONTROLLED ATMOSPHERES

Environmental test chamber (ETC); Monoterpenes; Secondary reaction products (SRP)

Maes, FM., Stranger, Marianne, Lor, Marc, Poelmans, David, Swinnen, Rudi, Goelen, Eddy



The ozonolysis of monoterpenes and their secondary reaction products (SRP) have been studied extensively in the past. Monoterpenes are ubiquitous indoors; their sources range from cleaning products to building materials. Ozone is generated by electronic equipment (printers, projectors), but its main source is infiltration from outdoor air.

Different groups of organic compounds can be formed because of gas-phase reactions of the unsaturated hydrocarbons (such as monoterpenes) with ozone to produce aldehydes, ketones and acids as its main components, together with the formation of ultrafine particles (UFP).

The current work presents a study on the influence of various environmental parameters (source light, variable limonene and pinene concentrations, and NO₂ on the formation of SRPs, based on realistic monoterpenes/ozone mixtures in environmental test chambers (ETC) using a variety of novel analytical techniques.

[Paper ID555](#)

ASSESSING THE RELATIONSHIP BETWEEN OUTDOOR AIR POLLUTION AND INDOOR AIR QUALITY IN NATURALLY VENTILATED CLASSROOMS: A CASE STUDY FROM CHILE

IAQ; Naturally ventilated schools; Particulate matter (PM)

Caceres-Araya, C. , Shrubsole, CS , Altamirano-Medina, HA ,

This paper presents the findings of a research study on the influence of outdoor pollution on the IAQ in naturally ventilated classrooms. The study was carried out in a school located in Rancagua (Chile), a city where annual average concentrations of PM₁₀ and PM_{2.5} have been found to exceed several times the maximum levels as recommended by the World Health Organization (WHO).

Classrooms were monitored and occupants surveyed to gain an understanding of the conditions affecting IAQ. In addition simulations using CONTAM, a validated software package, were carried out to predict movement of pollutants within classrooms. Results show that indoor concentrations of PM represent at least 40% of the outdoor levels even when ventilation is provided purely by infiltration (0.5 ACH). Ventilations rates above 6 ACH resulted in high indoor concentrations of PM₁₀ and PM_{2.5} (67 µg/m³ and 45 µg/m³ respectively), which are similar to concentrations found in smokers' apartments in Germany (Fromme et al. 2005).

This study suggests that natural ventilation may not be a good strategy for educational buildings located in areas with high levels of pollution, since penetration of pollutants was found to be high even in buildings with low infiltration rates, leading to negative health impacts.

[Paper ID556](#)

ENHANCE TOTAL HEAT RECOVERY FOR VENTILATION WITH FLASH EVAPORATIVE COOLING

enaporative cooling; total heat recovery; ventilation

Fang, FL. , Yuan, YS , Yang, Dr. ,



A new total heat recovery technology for ventilation was developed and tested in a lab. The developed heat recovery technology is based on the heat balance of moisture evaporating and condensing on both side of a plate heat exchanger. The design of the total heat recovery technology was to over saturate the rejected indoor air by an atomizer and let the incoming outdoor air exchange heat with the over saturated rejection air in a counter flow heat exchanger. The evaporation of the mist in the rejection air absorbs heat from the incoming outdoor air. This cooling process not only decreases the temperature of the incoming outdoor air but also makes the moisture in the outdoor air being condensed in the heat exchange and removed from the air for ventilation. An experimental test of this technology was conducted in a twin climate chambers. One chamber simulated warm and humid outdoor climate and the other simulated an air-conditioned indoor climate. Both temperature and enthalpy efficiencies were measured. The measured enthalpy efficiency of the total heat recovery could reach 60 to 70% which was 3.5 times higher than the enthalpy efficiency of the same counter flow heat exchanger without the flash evaporative cooling.

[Paper ID557](#)

THE ASSESSMENT OF ODOUR ANNOYANCE IN INDOOR ENVIRONMENT – A NEW CONCEPT USING STATISTICALLY DERIVED ACCEPTANCE LIMITS

naphthalene; odour threshold; PD-value

Schmidt, M.S. , Thumulla, J. T. , Krocze, C. K. , Lisow, W. , Mertens, J. M. , Weis, N. W. , Pilgramm, M. P. ,

In the past few years, a huge discussion has been going on about the assessment of odours in public and residential buildings. One of the many concepts developed has been published by the federal environmental agency and uses the Level of distinct Odour Awareness (LOA) based on the odour threshold and the Weber-Fechner equation.

We propose a new method involving the correlation between the concentration of an odorous substance and the statistically derived acceptance level. The correlation between the latter two can be determined by an experiment we have conducted deploying two substances - naphthalene (n=187) and 1-methylnaphthalene (n=23). The participants were supposed to evaluate the acceptance levels (+1....-1) of six different concentrations of naphthalene. According to the evaluations of each concentration offered, the acceptance levels as well as the PD-values (Percentage Dissatisfied) have been calculated. Thus, our examinations show that most of the participants rated the acceptance level negatively whenever the double concentration of naphthalene's odour threshold has been reached.

The prediction of the amount of dissatisfied people due to the correlation between the value of PD and the concentration of an odorous substance is a very powerful instrument in the assessment of odour annoyance in indoor environment.

[Paper ID559](#)

EXPERIMENTAL ANALYSIS OF SINGLE-SIDED VENTILATION THROUGH A CENTRE PIVOT ROOF WINDOW

centre-pivot roof window; onsite experiments; Single-sided ventilation

Iqbal, A.H.I. ,



In this study on site measurements were performed to characterise single-sided ventilation through a centre-pivot roof window (CPRW). Both wind and temperature differences were present at the time of measurements. Tracer gas technique using N₂O gas was used to estimate the air change rates (ACH) in the room. Leakages through the experimental space were estimated through a blower door test. ACH; increases linearly with increases in the sash opening angle. With an average wind speed of 4 m/s and when the window was maximum possible open the average ACH was 2. Flow factor was used to characterise the window. The flow factor of CPRW increased with increase in sash opening angle.

[Paper_ID560](#)

A MODEL FULL-SCALE EXPERIMENT FOR NATURAL VENTILATION IN A CUBIC STRUCTURE: THE REFRESH PROJECT.

Turbulence; Urban areas; Ventilation

Gough, H.L., Halios, C.H., Barlow, J.F.,

The urban microclimate has the potential to influence the effectiveness of ventilation in buildings in urban environments, in turn influencing the health and wellbeing of the building's occupants. However there is currently a lack of understanding of the interaction of the flow around a building and the indoor environment at full scale for naturally ventilated buildings. By combining the methodologies of both urban meteorology and engineering, a full scale experiment has been designed to answer two main questions: how do urban flows affect ventilation rate, and how does the positioning of openings affect the indoor environment? The experiment will also provide a full-scale data-set to test the effectiveness of CFD modelling of staggered arrays as part of the REFRESH project.

At the experimental facility at Silsoe, UK, a staggered array of nine 6m³ straw cubes was used to represent a simplified urban area, with one cube being instrumented internally. This cube had three ventilation modes; sealed, single-sided and cross-ventilated. Background meteorological conditions were recorded throughout the experiment. Tracer gas decay experiments were undertaken to gain an estimate of the ventilation rate of the instrumented cube, alongside long term indoor measurements of indoor temperature and wind-speeds in the openings.

[Paper_ID561](#)

MOISTURE AND THE INDOOR MICROBIOME

Fungi; Measurement; Moisture

Siegel, J.A.,

It is well-known that moisture problems in buildings can lead to negative health outcomes. However, there is inconsistent literature on whether the health effects stem from biological or chemical factors (or both). In order to make progress in understanding these health issues, as well as have a more mechanistic understanding of indoor microbial communities, it is imperative that we have accurate and microbially-relevant moisture measurement approaches. The central challenge to the development of such approaches is the complexity of moisture accumulation and transport in buildings. The purpose of this summary is to summarize current information on moisture measurement approaches and provide practical insight on their relevance for understanding indoor microbial communities.



[Paper_ID562](#)

THE ROLE OF SURFACES IN THE TRANSMISSION OF BIOAEROSOLS FROM SOURCE TO PATIENT IN HOSPITAL SINGLE AND MULTI-BED ROOMS

Airflow; bioaerosols; infection modelling

King, MFK. , Noakes, CJN , Sleight, PA ,

Aerial dispersion of bioaerosols and subsequent contamination of surfaces is recognised as a potential transmission route for health-care acquired infections. Pathogens accrue on health-care workers' (HCW) hands as they touch surfaces and can subsequently be transmitted to other patients.

Computational fluid dynamics (CFD) was used to predict bioaerosol deposition in a single and multi-bed hospital rooms. A Monte-Carlo model was developed using the CFD deposition patterns in conjunction with clinical observation of surface contact sequences to predict the contamination levels of bacteria on HCWs' hands as they perform patient care in the two rooms. Hand colonisation depends on care type, room layout and in particular on the spatial distribution of pathogens between surfaces, which is influenced by ventilation. During care within multi-bed rooms colonisation levels increase due to the spatial spread of microorganisms contaminating multiple patient surfaces caused by the ventilation strategy. Positioning infectious patients within an unobstructed path between the inlet and outlet diffuser significantly reduces cross contamination to other patients surfaces.

Colonisation levels of HCWs' hands are likely to be significantly lower after care in single patient rooms than after care in a multi-bed ward and ventilation design is vitally important in curtailing bioaerosol spread.

[Paper_ID563](#)

IMPACT OF SENSOR POSITION IN A ROOM ON THE ENERGY PERFORMANCE OF SPACE HEATING AND COOLING SYSTEMS

coupled simulation; energy performance; sensor position

Rösler, MR. , Felsmann, CF , Gritzki, RG , Kandzia, CK

Based on numerical simulations detailed information have been gained about the impact of the position of the room temperature sensor in a model room on the energy performance of the space heating or cooling system. Three different ventilation cases (mixing, personal and displacement ventilation) are analyzed. The numerical simulations were performed as coupled calculations of dynamic building behavior and Computational Fluid Dynamics. The simulation model has been validated by measurements in a climate chamber.

Generally, higher differences in energy performance could be observed in the cooling case. Both, in heating mode as well as in cooling mode the highest differences can be seen in the case of displacement ventilation. Finally, in the heating mode it is not possible to define an optimal sensor position that fits for all three types of ventilation because optimum sensor position is depending on the installed ventilation system, whereas in cooling mode the optimum sensor position is always the same.

In addition it becomes apparent than in all cases and for all sensor positions the criteria of the thermal comfort fulfill the demands of category A, given in ISO 7730.

[Paper_ID564](#)

ROOM AIRFLOW MEASUREMENTS IN A SIMPLIFIED ROOM GEOMETRY



benchmark; experimental investigations; room air flow structures

Kandzia, CK. ,

Because people spend most of their time indoors, it is important to learn more about thermal comfort and to get more information about different room air flow structures depending on isothermal and non-isothermal boundary conditions.

Numerical calculations on the one hand and experimental investigations on the other hand can be used to analyze the room air flow. The role of the numerical calculations is becoming increasingly important. Hence, it is necessary to validate these calculations using high quality experimental data.

Detailed measurements are carried out in a realistic model room, the Aachen model room (AMoR). Depending on the introduction of the supply air and the internal heating loads different types of room air flow structures occur in the AMoR. The measurement results of the speed and the temperature, including isothermal and non-isothermal boundary conditions as well as high and low inlet velocities, are presented for several measurement heights and planes. These results will be used as benchmark for room air flows.

[Paper_ID565](#)

MEASUREMENTS OF VOCs IN A LOW ENERGY BUILDING USING PTR-TOF-MS: COMPARISON OF INDOOR AND OUTDOOR BTEX MEASUREMENTS

Low energy building; Proton Transfer Reaction Mass Spectrometry; Volatile Organic Compounds

Ward, M.K.M. , Schoemaeker, C. , Locoge, N. , Dusanter, S. , Hanoune, B. ,

Pollutant levels are strongly dependent on ventilation rates in low energy buildings, which require the use of fast instruments to monitor indoor concentration profiles. The application of Proton Transfer Reaction Time-of-Flight Mass Spectrometry (PTR-ToF-MS) is a powerful technique in measuring the composition of Volatile Organic Compounds (VOCs) with a high temporal resolution. The soft ionisation of the PTR-ToF-MS technique results in low incidences of parent ion fragmentation, which in turn leads to a high selectivity, with no interference from abundant gases such as methane, carbon dioxide or water.

Two PTR-ToF-MS instruments (Mines Douai and Lille 1) using time-of-flight mass detection and a BTEX analyser (Lille1) were deployed during two measurement campaigns as part of the MERMAID program, in a low energy school building in France. A comparison of BTEX (C6-C8 aromatics) measurements made at three locations has provided information on the outdoor-to-indoor transmission of some these VOCs, as well as the efficiency of this system to reduce indoor pollutant levels. Certain VOC concentrations are typically lower outdoors than indoors, suggesting that their dominant sources are emissions from indoors. These measurements have also allowed an investigation of the contribution of indoor sources to the total VOC budget.

[Paper_ID566](#)

VOC EMISSIONS FROM OZONE INITIATED SURFACE REACTIONS WITH PVC FLOORING FROM A CLASSROOM

Ozone uptake; Proton transfer reaction mass spectrometry; Volatile Organic Compounds

Ward, M.K.M. , Mendez, M , Schoemaeker, C. ,



Ozone, O₃, is an important outdoor pollutant that is brought to the indoor air by ventilation. In most indoor environments, the ozone concentration is significantly lower than the outdoor one due to gas-phase reactions and surface removal. In this work, ozone deposition is considered as a surface reaction between ozone and unsaturated organics on a PVC material surface. These reactions produce pollutants that can be released into the gas-phase as secondary emissions. As part of the MERMAID project, which includes indoor and outdoor VOC quantification and measurements of surface emissions and sorption parameters, experiments on the heterogeneous uptake of O₃ on PVC flooring in an indoor school environment have been performed using a FLEC combined with a PTR-ToF-MS. The use of the PTR-ToF-MS provides sensitive quantification of VOC concentrations (ppbv) with a time resolution of 1-2 minutes. The observation of several VOC products formed due to the reactive uptake of O₃ has been made. As observed in the gas-phase chemistry of ozone, the ozonolysis of unsaturated organic species leads to the release of aldehydes. Concentration profiles of some species as well as O₃ have been used in optimising a model describing the uptake of O₃ onto a PVC surface.

[Paper ID567](#)

A CASE STUDY OF AIR QUALITY AND VENTILATION HABITS IN A SCHOOL / OFFICE BUILDING WITH NATURAL VENTILATION

Indoor air quality; Tracer gas measurements; Ventilation habits

Krajčík, M.,

In the older building stock ventilated by natural ventilation, the air quality strongly depends on the ventilation habits of the occupants. A case study of ventilation habits and the related air quality has been carried out in a university office building with a new high performance (in terms of buildings physics) façade. Whereas on the North-East this façade presents a simple glazed construction with the possibility to open the window to the exterior, on the South-West it is a double skin façade with a 20 cm gap between the two windows, not providing any possibility to open the window directly to the exterior, but only to the gap. The spaces investigated rely solely on natural ventilation by infiltration and by opening the windows and doors. The aim of the study was to identify the connections between users' behaviour in terms of opening doors and windows and occupancy patterns, and to calculate the air change rates by tracer gas decay method, using CO₂ as the tracer gas. The short summary presented provides the physical parameters monitored, compared with the standardized values as defined in EN 15251 (2007). The effect of users' behaviour and type of façade are briefly discussed, as well.

[Paper ID568](#)

THE ROLE OF DESIGN IN HEALTHY BUILDINGS – AN ACTORNETWORK PERSPECTIVE

Actor-network theory; Housing design; Indoor environment practices

Oeien, TBO.,



This paper is motivated by observations of indoor environmental concerns such as dampness and mold, perceived by residents of rental and private homes in Denmark. Based on actor-network theory (ANT), we have followed the network of interactions between the home and its associated actors in the field of indoor environment.

The ANT analysis shows a wide gap between the theory and practice of indoor environment. The phenomenon of mold growth can be inaccessible to laymen and makes it difficult for inhabitants to actively maintain a good and healthy living environment. Furthermore, the focuses on energy-efficiency and new technologies in construction reinforce the power of the specialist, to a degree where the user is excluded from the indoor environment network.

Because the arrangement and practices of a household is critical for a healthy home, we suggest that the user practices are taken into account in the process of designing, redesigning or adapting the indoor environment. To redirect the network of indoor environment towards convergence, we consider design as an opportunity to enhance the user as an actant.

[Paper_ID569](#)

OLFACTOMETRIC DETERMINATION OF THE ODOUR DETECTION THRESHOLD AND THE IDENTIFICATION THRESHOLD OF NAPHTHALENE

Naphthalene; odour detection threshold; PAH

Lisow, W., Schmidt, MS, Mertens, JM, Thumulla, JT, Weis, NW, Köhler, MK, Pilgramm, MP,

In Germany naphthalene indoor air emissions occur especially in older buildings (prior 1980's) due to commonly used tar containing construction products. High accumulations of PAH in indoor air are associated with health- and odour related peculiarities through naphthalene. For toxicological evaluation, German indoor guide-values can be used. For hygienic evaluation regarding the odour, an accepted odour detection threshold is missing.

To determine the detection threshold of naphthalene a two-day experiment was performed by using an olfactometer with 6 odour interfaces with 202 untrained participants. Naphthalene was supplied in ascending order between $\sim 0.7 \mu\text{g}/\text{m}^3$ and $\sim 70 \mu\text{g}/\text{m}^3$. The participants specify the first odour interface at which an odour was detected (odour threshold) and at which the specific smell of naphthalene was identified (identification threshold).

Analytical determination of the naphthalene concentrations was performed by air sampling with thermo-desorption tubes and analysis with TD-GC/MS. To determine the threshold levels, a log-normal probability-plot was used to define the median of the distribution.

The odour detection threshold for Naphthalene was determined at $2.3 \pm 0.8 \mu\text{g}/\text{m}^3$, the identification threshold is $8.8 \pm 3.2 \mu\text{g}/\text{m}^3$.

The results can be a reliable basis to derive odour guide values. Experts can use it to appraise indoor hygienic situations.

[Paper_ID570](#)

SENSORIC ODOUR TESTING ACCORDING TO DIN 16000-28 FOR THE EVALUATION OF BUILDING PRODUCTS - FIRST RESULTS

Building products; Sensoric odour testing; VOC emissions



Hofmann, HH. , Weis, NW , Mertens, Mt , Köhler, MK , Siemers, US , Neuweyer, BN , Nitschke, FN ,

Odour complaints are an important theme of the hygienic evaluation of indoor air quality. Accordingly the question of odour quality of products as a source of possible pollutions respectively to exclude sources increased.

In the past there was no harmonized and generally accepted method for odour measurements of building products. Different test methods were used for odour evaluation. By now there is an international harmonized and standardized test chamber procedure according to ISO 16000-28. Odour emission can be objectively evaluated on the basis of perceived intensity and hedonic tone.

The Bremer Umweltinstitut performs standardized VOC and odour tests according to the recommendations of the AgBB („Empfehlungen des Ausschusses zur gesundheitlichen Bewertung von Bauprodukten (AgBB)“) and the guidelines of DIN ISO 16000-3, -6, -9, -28 and VDI 4302 Part 1. First results of VOC and odour emission tests as part of the testing of construction products will be presented and the practicability of the procedure will be discussed.

[Paper_ID571](#)

ESTIMATING HUMAN THERMAL SENSATION REGARDING INHOMOGENEOUS INDOOR ENVIRONMENTS USING LOCAL ENERGY BALANCE EQUATIONS: A NEW APPROACH

energy balance; heat conduction; thermal sensation

Schmidt, C. , Wölki, D.W. , Grün, G. G. , Treeck, CvT van, ,

The paper contains a short overview on important thermal sensation/comfort models followed by an introduction of a new comfort model approach for the estimation of local and global thermal sensation/comfort. The model transfers Fanger's (Fanger, 1970) idea of calculating the body's energy balance on a global scale to local body segments. To be able to consider heat exchange between the human body and contacting surfaces, the original Fanger equations are extended by a heat conduction expression. The verification of the model's energy balances is introduced followed by an investigation on the predictive power of global thermal sensation. At the present state, the results show the general applicability of the model approach. Finally, an outlook on necessary parameterization and validation steps is given.

[Paper_ID572](#)

IMPROVING AIR TIGHTNESS OF STRUCTURES TO IMPROVE INDOOR AIR QUALITY

Air leakages; Improving air tightness; Repair method

Laine, KL. ,



Built environments contain microbes, particulate and gaseous impurities. For example, an aged building envelope commonly contains microbial impurities even when there is no obvious moisture damage. Removing the materials is not always possible or necessary. Indoor air quality (IAQ) problems attributable to such contaminated materials are commonly associated also with poor air tightness of the internal side of building envelope as well as unfavourable pressure conditions prevailing over the contaminated structure. Together these factors cause uncontrolled structural air leaks that convey impurities indoors. Air leaks have also a negative impact to energy efficiency and living comfort.

Improving air tightness of structures prevents uncontrolled air leaks and can be used to solve IAQ problems in buildings -usually in combination with other renovation methods. Improving air tightness requires planning, accurate execution on the construction site and supervision including quality control measurements. Careful implementation of the work is detrimental for the success of renovation. Several techniques have been implemented in order to prevent uncontrolled air flux through the structures since 1980's. Lately, IAQ related applications have been further developed and used as a part of successful IAQ renovations.

[Paper_ID574](#)

DEVELOPMENT OF A NEW INDEX FOR INDOOR PM2.5

air quality; fine particles; index

Säteri, J O. , Rantala, V

Fine particles in the indoor air are a major health concern. In a report published in the CAFÉ program in 2005 it is estimated 3.7 million years of life is lost annually inside the European Union due to particle pollution.

The exposure to fine particles indoors can be significantly reduced by air cleaners and filtration of supply air. The investments in ventilation and cleaning technology are often difficult to justify as the problem is not visible and the negative health outcomes are long term effects. The awareness of building users can be raised by measurement of fine particles indoor and visualization of the results.

This paper will present a suggestion for a PM2.5 indoor air quality index. The index is based on a visual five-step color based presentation on five different air quality classes. This index is intended to be usable globally for assessing the indoor fine particle concentrations. This index also takes the building air tightness and supply air filtration efficiency into account by introducing an I/O ratio to be fulfilled for the air quality categories.

[Paper_ID575](#)

SUBJECTIVE EXPERIMENTS ON RELATIONSHIPS BETWEEN INDOOR ENVIRONMENT AND AROUSAL STATE AND BETWEEN AROUSAL STATE AND WORK PERFORMANCE

Arousal state; Productivity; Work performance

Goto, T. , Koganej, M , Hiramatsu, M ,



The present study focused on arousal as one of the human physiological and psychological responses mediating the causal relationship between indoor environmental quality and performance. In order to investigate the role of arousal state, two subjective experiments were carried out. The first experiment was to verify that indoor environment affects occupants' arousal state. Indoor temperature, outdoor air supply rate and illumination intensity were changed at two or three levels (22, 25, 28°C; 10, 30 m³/h/person; 10, 300 lx), and six combinations of them were adopted as the experimental cases. A questionnaire was used to evaluate their arousal state with two dimensions of energetic arousal (EA) and tense arousal (TA). Skin conductance level was also used for objective assessment of their arousal state. As a result, EA tended to be low in the cases of poor IEQ, while TA tended to be high at the same time. The second experiment was to verify that arousal state affects performance. During the experiment, subjects performed three types of tasks (detecting wrong pairs of numbers, inputting numbers, and Sudoku), and indoor environment was not controlled. This experiment showed that subjects' performance became higher when EA was high, but became lower when TA was high.

[Paper_ID576](#)

SUBJECTIVE EXPERIMENT ON CAUSAL RELATIONSHIP BETWEEN INDOOR TEMPERATURE AND OCCUPANTS' PERFORMANCE MEDIATED BY AROUSAL STATE

Arousal state; Productivity; Work performance

Goto, T. , Koganei, M , Hiramatsu, M ,

In the present study, a subjective experiment was done to validate the causal relationship between indoor environment and occupants' performance mediated by their arousal state. Indoor temperature was selected as the environmental parameter, and controlled at three levels (22, 25, 28°C). The subjects' performance was evaluated with three types of tasks (detecting wrong pairs of numbers, inputting numbers, and Sudoku). The results were obviously dependent on the tasks. When subjects engaged in either detecting wrong pairs of numbers or inputting numbers, there were almost no differences in both arousal state and performance among three indoor temperatures. However, in the case of Sudoku, the EA at 22°C was significantly higher than 28°C (± 0.05) and the TA at 22°C was significantly lower than 28°C (± 0.05). A difference in performance on Sudoku was also found between 22°C and 28°C at the ending of the session (± 0.1). As the reason of the dependence on the tasks, it was considered that both EA and TA subsided due to the simplicity and monotony of the tasks except for Sudoku. Thus the EA and TA became lower regardless of the indoor temperature and no differences were caused in the performance.

[Paper_ID577](#)

INTRODUCTION OF THE EUROPEAN COMMISSION'S 7TH ENVIRONMENTAL ACTION PROGRAMME FOR VEHICLE INTERIOR AIR QUALITY - VIAQ

(S)VOC; 7th Framework; VIAQ

Widdowson, Caroline. , Calder, Hannah , Williams, James ,



This 3 year project, with a budget approx. 5 M €, is in line with the 7th Environmental Action Programme. The objective of the project is to protect the health and the environment of the vehicular interior from VOC emissions from materials used inside the cabin. The project will use an innovative method to obtain evidence, propose solutions and communicate to users, manufacturers and legislators. Many of these VOC emissions are not regulated in the EU, although they may have negative influences on human health and the environment. Furthermore, this project will reinforce Europe 2020, the EU 10-year growth strategy, stimulating innovation of green SME and increasing Europe competitiveness in developing new green technologies.

[Paper ID578](#)

HARMONISING ANALYSIS OF VOCs FROM SPRAY POLYURETHANE FOAM INSULATION

Microchamber; SPF; VOC

Widdowson, Caroline. ,

Spray polyurethane foam (SPF) insulation differs from conventional insulation in that it is applied by chemical reaction on-site, and the analytical testing can be difficult due to the need to measure potential (S)VOC emissions (e.g. blowing agents, catalysts, flame retardants, isocyanates). Consensus standards are being developed to evaluate SPF products for their impact on indoor air quality after installation in order to establish re-occupancy times for residents and re-entry times for trade workers. This presentation will discuss the ongoing development of ASTM International standard practices and test methods to measure chemical emissions from SPF insulation designed for on-site application in buildings.

[Paper ID579](#)

RADON EQUILIBRIUM FACTOR MEASUREMENTS IN AN AIR-CONDITIONED AUDITORIUM

Air-conditioning; Equilibrium factor; Radon progeny

Polednik, PB. , Grzadziel, GD , Dudzinska, DM , Bilska, BI , Kozak, KK , Mazur, MJ , Skwarczynski, M , Skwarczynski, M

The study on the impact of air-conditioning on the concentrations of radon and its decay products in an occupied and unoccupied auditorium is presented. The highest increase rates and decrease rate constants of radon and its decay product concentrations were observed in the AC on/off mode. The determined equilibrium factors, which take into account the concentrations of the attached decay products and the total decay product concentrations were highest in the AC off mode, they decreased in the AC on/off mode, and were lowest in the AC on mode.

[Paper ID580](#)

THE METHODS FOR EVALUATION OF INDOOR AIR QUALITY

carbon dioxide; evaluation; indoor air quality

Dobiášová, L.D.. ,



The indoor environment quality influences people's work performance and it can contribute to the health deterioration. This paper is focus on indoor air quality (IAQ), specifically on carbon dioxide (CO₂) and its using for evaluation of IAQ. The methods for evaluation of IAQ are briefly described (percentage of dissatisfied with IAQ, evaluation using the decibel concept and evaluation by method of tracer gas CO₂). The next part is application described methods on case study. The final part is evaluation of used methods.

[Paper ID581](#)

OPERATIVE TEMPERATURE DRIFTS AND OCCUPANT SATISFACTION WITH THERMAL ENVIRONMENT IN THREE OFFICE BUILDINGS USING RADIANT HEATING/ COOLING SYSTEM

Operative temperature drift; Radiant heating/cooling; Thermal comfort

Kolarik, J., Toftum, J, Olesen, B. ,

The objective of this study was to analyse operative temperature drifts and occupant satisfaction with thermal environment in office buildings utilizing embedded radiant heating/cooling systems. Three office buildings were investigated: Town Hall in Viborg, Denmark (floor area 19400 m²), IDOM, Madrid, Spain (16000 m²), TiFS, Padua, Italy (2200 m²). Continuous measurements of operative temperature were conducted at four workplaces in each building for one year. Occupants' satisfaction was assessed by internet based questionnaire. Results showed that mostly exceeded limits were those for 4-hour drift (0.8 K/h), which were exceeded at least in 2% and up to 52% of occupied time in investigated buildings. Limits for hourly and 2-hour drifts were exceeded in max. 2% of occupied time. Median values were in ranges of 0.12-0.29 K/h, 0.18-0.52 K/h and 0.27-0.84 K/h for 1, 2 and 4-hour drifts respectively. Occupants' in all buildings were rather satisfied with temperature conditions. Median temperature satisfaction (0='Clearly satisfied' - 5='Clearly dissatisfied') was 2, 1 and 1 for Viborg, Madrid and Padua respectively. Temperature satisfaction slightly decreased when rate of temperature change increased, thus higher temperature drifts seemed to lead to higher dissatisfaction, however the collected data did not allow for robust statistical analysis.

[Paper ID583](#)

ANALYSIS OF TOTAL CELL COUNT IN BUILDING MATERIAL - A NEW WAY TO ASSESS MICROBIAL CONTAMINATION AFTER WATER DAMAGES - DETERMINING THE MICROBIOLOGICAL TOTAL CELL COUNT IN BUILDING MATERIAL, USING FLUORESCENCE MICROSCOPY WITH ACRIDINE ORANGE

fluorescence; mold; total cell count

Meider, JM. , Dr. Palmgren, UP



The total cell count is a microbiological analytic which enable the detection of the biomass on building material. Mold inside buildings have an allergic and toxic potential irrespective of the viability of the cells. The analysis of the colony forming units (CFU) only detects the viable cells within the biomass. To draw conclusions of the detected colonies to the total biomass is not possible. Lack of water or chemical substance prevent microorganism from growing but the biomass is present does not matter if the CFU grow or not. The allergic or toxic potential is present even if the CFU cannot detect.

The analysis of total cell count in building material enables the appraiser to localise the microbial damage very fast and decisions of a technical drying or mold remediation can be taken much faster. Within one day results can be presented by the laboratory. So far adhesive tape analysis could offer fast results like this but only on smooth surfaces. Colony forming unit could investigate materials with rough surfaces or deeper layers but the growing of the colonies take time.

[Paper_ID584](#)

MEASUREMENTS OF THE PERCEIVED AIR QUALITY IN SHOPPING CENTERS

emissions from goods; perceived air quality; perceived intensity

Müller, D., Panaskova, JP, Hegemann, D., Dr. Braunstein, VB

The experimental study shows the effects of olfactory-relevant emissions from goods in a shopping center and its link to the building energy demands. The indoor air quality shall be acceptable in all zones without wasting energy by unreasonable high ventilation flow rates. The study aims to minimize the ventilation rates in shopping centers to save energy without disregarding the indoor air quality. The first part of this ongoing investigation that is presented here comprises clothes, shoes and books/magazines as three typical product groups. All goods are examined under laboratory conditions in the air quality lab of the E.ON Research Center. Eight subjects evaluated the emissions regarding the olfactory parameter “perceived odor intensity” also called “perceived intensity” using an acetone-air reference scale. The subjects’ ratings on each product group are put in relation with the rate-specific load per unit area resulting in characteristic exposure-response functions. The data show that the emissions from these product groups lead to different characteristic exposure-response functions. This research in shopping centers provides an indicator of well-adjusted ventilation rates at different product group zones.

[Paper_ID585](#)

CHANGES OF RADON AND ITS DECAY PRODUCT CONCENTRATIONS IN AN AIR-CONDITIONED AUDITORIUM

Aerosol particles; Radon; Radon progeny

Bilska, IB., Polednik, BP, Dudzinska, MD, Kozak, KK, Mazur, JM, Grzadziel, DG, Siuta-Olcha, ASO, Skwarczynski, MS



The research results concerning the impact of the air-conditioning system on the dynamics of radon and its decay product concentrations are presented. Out of the three considered AC operation modes: AC off, AC on/off and AC on, the highest and the most regular changes of radon and its decay product concentrations were found during the variable conditions in the AC on/off mode. Positive correlations were found between the concentrations of attached decay products and particle number and particle mass concentrations in all three AC modes. Such correlations for radon concentrations were only present in the AC on/off mode.

[Paper ID586](#)

THE OPTIMISATION OF A NEW LOW VOLUME AIR SAMPLING METHOD FOR THE DETERMINATION OF FLAME RETARDANTS

Air monitoring; Flame retardants; Mixed bed sampling

Lazarov, BL. , Stranger, MS , Maes, FM , Lor, ML , Swinnen, RS , Spruyt, MS , Goelen, EG , Covaci, AC

An analytical methodology using automatic thermal desorption and GC-MS was developed for the determination of selected flame retardant chemicals (e.g. PBDE-28, PBDE-47, PBDE-66, PBDE-85, PBDE-99, PBDE-100, TNBP, TPP, TCEP, TDCIPP, TEHP, TPHP, TCIPP and TMPP) in air. The methodology is based on low volume active sampling of gaseous and particulate air fractions on mixed bed (polydimethylsiloxane (PDMS) / Tenax TA) sorption tubes. The optimized method provides recoveries; 88%, a limit of detection in the range of 0,006-0,025 ng m⁻³ for polybrominated diphenylethers (PBDEs) and 0,006 – 0,171 ng m⁻³; for organophosphate flame retardants (OPFRs), a linearity greater than 0,996 and a repeatability of less than 10% for all studied compounds. The optimized method was compared with a standard method using active air sampling on XAD-2 sorbent material, followed by liquid extraction.

[Paper ID587](#)

DESIGN IN THE WORKPLACE - THE BIOPHILIA IMPERATIVE

Biophilic; Health; Productivity

Arkel, J.G. ,

The concept of biophilia highlights an innate connection between humans and nature, which more recently has been recognised as a key consideration when designing and developing workspaces. The idea of incorporating nature into the built environment through biophilic design is less often seen as a luxury in the modern workplace, but rather as a sound economic investment into employees' health, well-being and performance. What makes work feel good? For modern organisations and their people, it's about much more than the end goal of productivity and profit. How we gain meaning, a sense of well-being and of purpose in the workplace is just as vital, not only to feel good but to perform effectively too. Increasingly, employers and employees themselves are engaging in this debate about a more comprehensive view of work and the role it plays in our lives, as are governments and societies with the growth of projects measuring national well-being across the world.

[Paper ID588](#)

INDOOR AIR QUALITY IN 34 NURSERIES IN BRUSSELS

Green Ambulance; Indoor Air Quality; Nurseries



Bladt, S. , Wanlin, M , Lecointre, C , Liebens, C , Vanderslagmolen, S , Chasseur, C

Literature clearly shows that exposure to indoor air pollution at an early age enhances the risk of acute lower respiratory system infections in children under the age of 5 years. In this framework, the Regional Unit for Indoor Pollution Intervention performed a study on the indoor air quality in nurseries in Brussels.

34 nurseries (2006-2014) were sampled for total Volatile Organic Compounds (VOCs), formaldehyde, lead in paint, CO₂, moulds, and bacteria in air and in surface, dust samples. In addition, noise measurements were performed. A questionnaire dealing with the daily maintenance and ventilation of each nursery was completed in order to obtain an inventory of potential sources of indoor pollution.

Of all VOCs measured, limonene was present in the highest concentration. Although only five nurseries showed average limonene concentrations higher than 60 µg/m³, the long-term effects of low doses remain currently unknown. Furthermore, 57% of the investigated playrooms contained CO₂ concentrations exceeding the French reference value of 1000 ppm pointing to a clear lack of appropriate ventilation. Poor ventilation rates resulted also rather often in high airborne bacterial concentrations (53% exceeded 1000 CFU/m³). Noise levels in the playrooms were generally higher (65.2-73.9 dB(A)) than the WHO guideline values (35 dB(A)).

[Paper_ID589](#)

AN ANALYSIS OF INTEGRATED EXTERIOR SHADING AND INDOOR LIGHTING CONTROL FROM OPERATION LEVEL

Daylight utilization; Dimmable lighting control; Energy Efficiency

Sun, J. , Li, Z. Xiao, F.

The integration of exterior shading device and indoor lighting control theoretically provides a reasonable method to solve the excessive solar heat gain accompanying the admission of outdoor illumination, so as to maximize the potential of energy saving in both air conditioning and lighting systems. While most researches on this topic are taken in design stage and focusing on the overall energy consumption over a relatively long period, this paper tries to analyze this topic from a more practical perspective. In operation stage, the economy of daily performance and the actual operation cost are the real concern of both users and owners of the building. Simulation is applied with EnergyPlus and time-of-use electric price has been used in calculation. The result shows that even for the case considered as the most energy efficiency in design stage, it may still not be the optimal in daily operation and actually cost more money. Such contrast suggests there is still much space for optimization and they should be done from the perspective of operation level.

[Paper_ID590](#)

A MEASUREMENT SETUP TO TEST INSTRUMENTS FOR DETECTING SWEAT

comfort; sweat detection; thermal neutral zone

Verhaart, J. , Snoeren, R. , Li, R. , Zeiler, W.



The thermal neutral zone is the temperature range in which the body can manipulate the heat balance of the body using only vasomotion to maintain thermal comfort. In a warm environment, vasodilation will allow blood and heat to spread over a larger surface area, increasing the heat loss through passive means. When the heat loss needs to be increased further, people start sweating and the heat is lost by evaporating moisture from the skin. Sweat can be used to monitor the thermoregulatory response of users and test subjects. This is similar to skin temperatures. Detection of the onset of sweating is an indicator for the upper boundary of the thermal neutral zone. Up until now, detecting vasomotion, sweat and sweat rate requires highly controlled conditions and complicated instruments. There is a need to develop instruments that can be used in an office environment during field tests for the development of personal conditioning systems and future climate control systems. In this study, a test set up is build that can mimic the human skin with respect to temperature and sweat rate. Based on the results of the study suggestions are given for the further improvements and measurements on the human body.

[Paper ID591](#)

REDUCING THE RISK OF VOC EMISSIONS: A PRODUCT EMISSIONS REVIEW

Certification; Standards; VOCs

Black, MSB. ,

There are many potential sources of indoor air pollution in homes and buildings, including building materials, furnishings, cleaners and other products used indoors. Considering that source control is the most effective means of preventing indoor air pollution, reducing VOC emissions from products is a critical aspect of protecting human health. Over the past 12 years, GREENGUARD, a third party testing and certification program has verified over 15,000 products and studied the emissions of over 35,000 materials and finished products. We provide a review of primary VOCs emissions from product types including office furniture, children's furniture, paints and coatings, insulations, adhesives, wall coverings, floor coverings, and electronics. VOC data from specific product categories are grouped by frequency of detection and hazardous risk categories according to VOC regulatory lists. Data trends over time show a reduction in the number of chemicals detected on key criteria lists, and reductions in key pollutant levels with defined health risks like formaldehyde. Data also show that numerous odorant and irritants are detected but that the majority of VOCs found are not on key hazard lists. Emissions data is critical in assessing the health impact of indoor materials and seeking steps in reducing risk of human exposure.

[Paper ID593](#)

BENCHMARK AND REQUIREMENT TO COMFORT LEVELS BY USE OF ACTIVE HOUSE TOOLS

Air quality, Daylight evaluation,; Nearly Zero Energy Buildings; Thermal comfort, Guideline,
Eriksen, KEE. ,



Design of sustainable buildings needs a holistic approach where all crucial aspects are taken into consideration in the early design process. Energy efficiency is one of the main issues discussed for sustainable buildings today and needs to be evaluated.

However as people spend up to 80-90% of their time inside buildings, it is imperative that the development of sustainable buildings also has a strong focus on the indoor comfort and human health aspects. In addition, it's important for sustainable buildings to consider their impact on key environmental issues and reduce their carbon footprint,

The Active House Vision adopts this holistic approach with a balanced focus between the comfort, energy and environmental aspects of residential buildings. The paper discuss the need for this holistic approach and will present a number of design aspects from existing projects based on the Active House Guidelines within Comfort, Energy and Environment buildings. The guidelines give specific focus on the design process and examples on how the daylight conditions can be optimized in buildings and how indoor climate can be optimized in warm climates using passive technologies, shading etc.

[Paper_ID594](#)

MEASUREMENTS OF CAPTURE EFFICIENCY OF RANGE HOODS IN HOMES

Capture efficiency; home; Range hood

Simone, A., Sherman, M.H.S., Walker, I.S.W., Singer, B.C.S., Delp, W.W.D., Stratton, J.C.S.

Higher airtightness homes, as the near zero energy buildings, may raise the demand and the need of better kitchen ventilation with higher efficient capture of the main pollutions source definitely resulting by his cooking process. Every home has a kitchen, and an effective, low energy and silent hood will be ideal. The available guidelines/standards could not be sufficient and applicable to guarantee and satisfy manufactories and homes occupants' health. In the paper, after a set of measurements conducted in a tight kitchen-room built in a laboratory chamber, a methodology for measuring and test the capture efficiency of a range hood is discussed. The data analyses, resulting when using a wall mounted range hood, showed a maximum of 50% of pollution escaping from the front side of the cook-top at 230 m³/h exhausting airflow. A more accurate analysis, by mapping the pollution distribution in the room, showed that the pollution gasses may more escape at the exhausting plume from the sides. Those results suggest that more measurements should be conducted investigating the capture efficiency at different pan's temperature, size and location, and for different range hood type and positions height.

[Paper_ID596](#)

THE PSYCHOLOGY OF THERMAL COMFORT: INFLUENCES OF THERMO-SPECIFIC SELF-EFFICACY AND CLIMATE SENSITIVENESS

climate sensitiveness; specific self-efficacy; thermal comfort

Hawthornt, M.H., Schweiker, M.S., Wagner, A.W.,



Thermal comfort is described in the adaptive comfort model as being influenced by physiological, behavioural and psychological adaptive processes. However, the concept of psychological aspects is not sufficiently described yet. To investigate influencing factors on thermal comfort, a field study in summer time was conducted. To get a better understanding of the psychology of thermal comfort, a focus was on personality traits, the feeling of control over the environment and preferences of temperatures (e.g. heat sensitive). The subjective assessment included the ASHRAE- and related scales, but also self-evaluated items regarding e.g. valence, arousal, and actual and desired control. A new questionnaire concerning perceived self-efficacy in the thermal environment was developed. Perceived self-efficacy is described as the expectation to be able to execute desired actions. In addition, physical data like temperature and humidity of the indoor environment in naturally ventilated and mixed mode office buildings were recorded together with subject's physiological data. Results show relationships between personality traits, thermal perception, physical and physiological measurements, e.g. people who are cold-sensitive seem to have another thermal sensation than not cold-sensitive people. Also people who are sensitive to indoor thermal environments experienced another self-efficacy relating to temperatures than non-sensitive people.

[Paper_ID597](#)

REVISITING VALIDATION METHODS OF OCCUPANT BEHAVIOUR MODELS

building performance simulation; Model validation; Occupant behaviour modelling

Wolf, S.W. , Schweiker, M.S. , Wagner, A.W. , Treeck, C. van ,

The relative impact of human behaviour on the energy performance of buildings has increased in the recent years as insulation standards have improved. On this account research focuses increasingly on occupant behaviour. Today several models on occupants' presence and interactions with the built environment exist. However, studies show that these models are not able to make reliable predictions in environments different from the one they were trained on. One important step in model development is the validation process. To assess the general predictive performance of a model it needs to be tested on data from independent built environments and human subjects. Most past validation processes are limited to the comparison of the simulation outcome to data gathered in the same context in which the model was developed. This leads to an overestimation of the model's performance. Fortunately there has been extensive work done on model validation in other fields of research which can be used also for the purpose of occupant models. This work reviews the existing approaches of model validation developed for occupant behaviour. Furthermore it adds more well established statistical methods suitable for the application in future validation processes and gives recommendations for a standardized approach.

[Paper_ID598](#)

URBAN POLLUTION AND INDOOR AIR QUALITY, AN UNDISPUTED RELATIONSHIP: CFD MODELLING OF SINGLE-SIDED POLLUTANT INGRESS

Building CFD; pollutant ingress;

King, MFK. , Noakes, CJN , Barlow, JFB ,



This study simulates near-field pollutant dispersion and subsequent ingress into building envelopes within urban street canyons via computational fluid dynamics (CFD). Qualitative pollutant dispersal experiments conducted in wind tunnels are compared against numerical simulation.

Two street-canyon aspect ratios were investigated (Height/Width=0.5 & 1). Roof angles were investigated (flat and 26.6°). An open window was located on the on the leeward side connecting to an interior room. ANSYS Fluent 15 was used to model airflow and employed a k-omega turbulence model. CO2tracer was released between the buildings and concentrations were measured inside the open window.

Increasing canyon width reduced the residence time of pollutant and reduces ingress. Flat roofs for both ratios drew CO2 to the leeward side of the building due to negative pressures. However pitched roofs created more complex systems that reduced contaminant in the canyon due to unsteady vortices. This may indicate a decrease in vertical exchange due to intermittent turbulent structures which maintain overall mass transfer with the air above.

[Paper ID599](#)

AIR EXCHANGE RATES AND MIGRATION OF VOCs IN BASEMENTS AND RESIDENCES

Air Exchange Rates; Basements; VOCs

Batterman, A. , Du, Liuliu , Godwin, C , Rowe, Zachary , Chin, JY , Breen, M

Basements affect IAQ in many ways. They contain potential VOC sources. VOC contamination in soil and groundwater can enter basements; vapor intrusion (VI) of both chlorinated and petroleum hydrocarbons can be a serious problem. Basements can form part of the living space and thus constitute an important fraction of the interior volume, and basements participate affect the building's air exchange rate (AER).

We conducted a VOC and AER measurement campaign in over 60 residences in Detroit, Michigan. VOC measurements were collected at several sites in both basements and the larger rooms in each homes. AERs for the basement and the remainder of the house, and flows between these two compartments, were determined using a steady-state multi-tracer system. A walkthrough survey was conducted.

AERs averaged 0.51 and 1.52 h⁻¹ in houses and basements, respectively, and varied seasonally. The air flow from the basement to the house also varied seasonally. Indoor VOC concentrations were skewed, and 90th percentile concentrations of benzene, toluene, naphthalene, and limonene were 4.0, 19.1, 20.3 and 51.0 µg m⁻³, respectively. Basements contained important VOC sources, e.g., household cleaners and gas-powered tools. Basements contributed 15-27% of the indoor concentrations, and in some cases, much more.

[Paper ID600](#)

REQUIREMENTS AND TESTING TO SECURE INDOOR AIR QUALITY – MALODOROUS POLYPROPYLENE FOIL – A METHOD STUDY

Odour; Test methods; VOC

Jönsson, M. , Gustavsson, PEG , Bude, MB , Larsen, AL



IKEA offers home furnishing solutions for every room in the home. In order to ensure that the products are safe for customers from a health perspective the requirements has developed continuously. In addition to safety issues, emissions of annoying odours will have negative influence of the experienced quality of products. Different test methods can be used to secure these aspects of product quality. Here sensory and chemical test methods are combined and compared in an investigation of a malodorous polypropylene foil. This combination of test methods can be valuable in evaluation of odour and emission problems and are useful to secure minimal impact on indoor air.

[Paper ID601](#)

EXPOSURES IN HOMES, SCHOOLS AND COMMUTING MICROENVIRONMENTS: THE SIGNIFICANCE OF TRAFFIC-RELATED AIR POLLUTANTS FOR CHILDREN

Air exchange rates; Exposure; Schools

Batterman, A. , Breen, M

Deficient IAQ in schools can adversely affect the health, academic and attendance of students. Unfortunately, environments and ventilation in schools often are inadequate. Many schools are near major roads, and traffic-related air pollutants may be present indoors. This paper aims to improve the understanding of exposures in school, home and commuting environments for school children, with a focus on traffic-related pollutants.

We estimated daily and long-term concentrations of particulate matter (PM_{2.5}), black carbon (BC), and nitrogen dioxide (NO₂) in schools, homes and commuting microenvironments, and apportion exposures to these microenvironments. A hybrid air quality model is used to estimate ambient concentrations at over 200 homes, 100 schools, and selected commuting routes in Detroit, Michigan. Indoor concentrations are predicted using a mass-balance model, air exchange, penetration and deposition rates. Exposure estimates in school, home and commuting microenvironments are derived.

For school children, exposure occurs primarily in homes and schools, and commuting exposure is secondary since commutes for most children are short and do not occur on highways. However, variability is high. For NO₂ and BC, traffic-related sources constitutes the major source; for PM_{2.5}, traffic-related emissions can be important for children living or attending schools near major roads.

[Paper ID602](#)

ENERGY CONSERVATION AND IMPROVED IAQ WITH EXISTING VENTILATION STANDARDS

energy conservation; indoor air quality; ventilation

Muller, C. O. , Bennett, D. , Edeling, A. , Zouggar, Y.



The Indoor Air Quality (IAQ) Procedure described in ASHRAE Standard 62.1-2013, "Ventilation for Acceptable Indoor Air Quality", is an alternative performance-based method for determining minimum outdoor air ventilation rates. However, due to perceived deficiencies in methodology and application, the IAQ Procedure has been an 'on-again, off-again' HVAC design approach. Due to increasing momentum for more sustainable, greener building design with the concurrent demands for increased energy efficiency and IAQ, there is renewed interest in this method. Properly applied, the IAQ Procedure can provide for considerable HVAC-related energy savings along with significant improvements to IAQ. This paper provides an update on current activities related to the IAQ Procedure with regard to Standard 62.1; ASHRAE TRG4.IAQP for development of the Indoor Air Quality Procedure; U.S. Green Building Council LEED pilot credit EQpc68, and case studies describing successful application of the IAQ Procedure in a LEED building project. Additional information will be provided describing practical applications of the IAQ Procedure along with examples that illustrate capital, HVAC equipment, and system renovation savings as well as energy savings possible by employing the IAQ Procedure.

[Paper ID603](#)

A PRACTICAL DATABASE APPROACH FOR LEVERAGING CATALOGUES OF FLUORESCENT SIGNATURES FOR REAL-TIME BIOAEROSOL ASSESSMENTS OF THE BUILT ENVIRONMENT

Bioaerosol; Fluorescence; Monitoring

Hernandez, T. ,

Bioaerosols are ubiquitous and their rapid characterization has wide relevance for built environment assessment applications. Recent technological advances have facilitated real-time characterization of airborne particle fluorescence as a consistent bioaerosol indicator; this leverages single-particle excitation at one or more ultra violet (UV) wavelengths, followed by the immediate recording of associated emissions. UVIF has been used to detect bioaerosols in both laboratory and field studies, where primary biological airborne particles (PBAP) are reported to compose a significant fraction of supermicron aerosol. While many PBAPs can fluoresce, interpreting UVIF measurements for bioaerosol characterization (recognition) presents challenges that can be better addressed using referenced fluorescence emission distributions of actual airborne microbes. Using accepted chamber practices, we present here an optical laboratory characterization of pure cultures of common airborne bacteria, fungi and pollen grains. This was extended to compare distributions of fluorescent particles that represent bioaerosols in large regional sampling campaigns of water damaged structures.

[Paper ID604](#)

A PERSPECTIVE ON LEVERAGING NEW GENERATION SEQUENCING FOR BIOAEROSOL ASSESSMENTS OF THE BUILT ENVIRONMENT: DIFFERENCES AND COMMONALITIES OF PROCESSING PIPELINES AND DATABASES

Bioaerosol; DNA Sequencing; Ecology

Hernandez, T. , Robertson, E



A number of recent built environments studies have used “next-generation” high throughput DNA sequencing to characterize surface associated and airborne microbial communities in residential and commercial buildings. Along with ultra-clean sampling methods need for this forensic approach comes the requirement for substantial computational power, tailored software, relational databases, as well as modest computer skills. Once samples are acquired, they can now be outsourced to specialty laboratories for sequencing and reports on the relative abundance of the microbes collected?as would conventional aerobiological samples. Most of these high throughput analyses target and report relative abundances using the most accepted evolutionary genes used for “identifying” bacteria and fungi; however, the data analyses from these types of studies can be tenuous because of a complicated conglomerate of “ubiquitous (processing) artifacts”. Given the rapid maturation and availability of “high throughput sequencing” we present here the range of processing pipelines and databases which are now available to the science, engineering and industrial hygiene community for this purpose. We present the basic computational tenants of the major pipelines, as well as the characteristics of the relational databases they use for determining the relative abundance in surface and aerosol samples recovered from the built environment.

[Paper_ID605](#)

DEVELOPMENT OF AN ENVIRONMENTAL OBSERVATION SCALE FOR THE INDOOR VISUAL ENVIRONMENT.

environmental factors; low vision; nursing home

Sinoo, MM. ,

INTRODUCTION: Lighting and colors and contrast are known to have a positive effect on visual functioning of older adults. The highest estimated prevalence ($\pm 40\%$) of visual impairment in the Netherlands, has been found in nursing homes. An observation scale was developed to evaluate a healthy environment for the (visual impaired) nursing home resident. **METHODOLOGIES:** Based on the literature, environmental parameters of the Environmental Observation scale for the Visual Impaired (EOVI) were defined. In a two round Delphi study professionals determined the domains, and the items within these domains. **RESULTS AND DISCUSSION:** The domains of the scale are ‘illuminance’, ‘the use of color and contrast’ and ‘obstacles’. The scale evaluates common rooms of a nursing home ward and can be used to improve the environment. To reach content validity in total 27 items of the common rooms were judged by experts. Of common rooms 1 item was maintained, 16 were adjusted, 7 new items were added and three items were removed. **CONCLUSION:** The content validity for the domains and items was performed for the common rooms. To have a tool to evaluate visual performance conditions of nursing homes, the same procedure will be used for the corridors and bathrooms.

[Paper_ID608](#)

INDOOR AIR QUALITY VS. ENERGY USE IN A BEER BREWERY: ASSESSMENT OF VENTILATION METHODS AND SYSTEMS USING CFD

CFD simulations; CO2 emission; Indoor airflow modelling

Hooff, T.. , Blocken, B.



The production in industrial buildings can have a large impact on the indoor air quality. For example, in beer breweries several processes influence the indoor air quality to a large extent, such as the fermentation process, which is accompanied by a strong emission of CO₂ gas. Employees working inside this kind of rooms can be exposed to high CO₂ concentrations. This paper presents Computational Fluid Dynamics (CFD) simulations to analyze three different ventilation configurations for an enclosure in which a fermentation process results in high CO₂ emission levels. High-resolution steady 3D Reynolds-averaged Navier-Stokes (RANS) simulations were used to assess different ventilation methods and system designs, with the aim to realize a healthy indoor environment using a minimal amount of energy. The results showed that the ventilation configuration should be designed in such a way that it optimally takes advantage of the density difference between the ambient air and the released CO₂ gas. In this particular case, a highly uniform downward directed flow using a low supply velocity showed the best performance (lowest CO₂ concentrations), with a similar supply volume flow rate as used for the other configurations (and thus equal energy use).

[Paper ID609](#)

RETROFITTING WITH SUSTAINABLE BUILDING MATERIAL - VOC, RADON AND THORON IN INDOOR AIR AFTER HOME ENERGY SAVING REFURBISHMENT

IAQ; Radon; Refurbishment

Daeumling, ChD. , Brenske, KHB , Hoffmann, BH ,

Home energy saving is accepted as an overall goal in politics as well as in private provisions for wellbeing and economic sustainability. The refurbishment of the upper floor with ecological building materials of an old farmhouse gave the opportunity for a case study. Commitment to energy saving and sustainability led to the choice of wood fiber insulation in the wind tight roof, air tight windows, and local pine wood flooring. Modern clay wall elements were used to provide healthy indoor climate for their moisture and temperature buffering properties. The two house levels, the refurbished upper floor and the untouched ground floor were compared in regard to VOC, radon and thoron, and air exchange dynamics which all contribute to the final indoor air quality.

[Paper ID610](#)

INFUENCE OF A BREATHING PROCESS ON DISTRIBUTION OF AIR FROM A PERSONAL VENTILATION OUTLET

breathing process; personalised ventilation; thermal manikin

Bogdan, AB. , Koelblen, B , Chludzinska, M ,



Personal ventilation (PV) enables shaping a micro environment around a human in such a way so as to ensure the highest standards of air quality and thermal environment without detriment to users' thermal comfort. The basis of the correctly designed personal ventilation lies in properly selected air distribution around a human which takes into account natural thermal plume generated by a human body.

The study aimed to assess an influence of a breathing flow on a distribution of air from a PV outlet. Tests were made on a thermal manikin called Newton. Given that the thermal manikin is equipped in a breathing function, the experiments were divided into non-breathing and breathing variants. The analysis of an influence of PV was based on equivalent temperature (T_{eq}) calculation. Additionally, thermal insulation was determined for clothes and chair on which the thermal manikin was seated (taking into consideration a desk). The tests provided grounds to determine that an air flow exhaled by a human influenced the direction and development of an air flow coming out of a PV outlet.

[Paper ID611](#)

LABORATORY TESTS OF IN SITU METHODS OF PCB EXTRACTION FROM CONTAMINATED BUILDING MATERIALS

concrete; NMTS paste; remediation

Frederiksen, MFR. , Gunnarsen, LBG , Andersen, H.V. ,

Three different methods for "in situ" extraction of PCBs from concrete were tested. The methods were: Non-activated Metal Treatment System (NMTS), clay plaster with ethanol and an activated carbon gel with propylene glycol and ethanol. The methods were tested on concrete blocks from a contaminated building, which were treated, cut up and analysed in small fractions to yield information on the penetration profile. The results showed an exponential decrease in the control sample, while a steeper decline was observed for clay and carbon treatments, and for NMTS a very flat curve was observed. The congener profile changed through the blocks (generally being enriched in lighter congeners further into the concrete), except after NMTS treatment, where a uniform congener distribution was observed. This indicated that NMTS not only removed PCBs from the block, it also redistributed and transported them further into the concrete. Finally, the observed extraction efficiency of the tested methods was 15%, 7% and 10% for NMTS, clay plaster and activated carbon gel, respectively. Thus, all methods showed potential for "in situ" PCB extraction, though common for all was that several consecutive treatments would be required in order to obtain a substantial reduction of PCBs in the treated concrete.

[Paper ID612](#)

PREDICTION OF POLLUTANT DISPERSION IN BUILDINGS: ANALYSIS OF THE GRADIENT-DIFFUSION HYPOTHESIS

CFD modeling; Pollutant transport modeling; Turbulent flows

Hooff, T. , Blocken, B. , Gousseau, P , Heijst, GJF van , ,



Numerical simulations of room airflow using Computational Fluid Dynamics (CFD) are often based on the Reynolds-averaged Navier-Stokes (RANS) approach. Using this approach, only the averaged quantities are computed, whereas the effect of turbulence on the mean flow is modeled. Since the RANS approach does not provide information on velocity and concentration fluctuations, also the turbulent mass fluxes should be modeled. In the majority of the cases this is done by employing the standard gradient-diffusion hypothesis, which relates the turbulent mass flux to the mean concentration derivatives. In this paper a CFD analysis of pollutant dispersion in an enclosure ventilated by a transitional wall jet ($Re \sim 2,500$) is presented, using validated high-resolution RANS and Large Eddy Simulations (LES). The LES simulation shows that a counter-gradient turbulent mass flux is present, indicating that the standard gradient-diffusion hypothesis used in RANS is not valid in the entire flow domain. However, it is shown that for this particular case, the convective mass fluxes dominate over the turbulent mass fluxes, and that the predicted pollutant concentrations by RANS will therefore not differ significantly from those by LES.

[Paper ID613](#)

PROPOSAL OF THE CEMENTS' ECO-LABELLING CRITERIA EXTENSION

Barium; Hexavalent chromium; Lead

Estokova, AE. , Palascakova, L , Kridlova-Burdova, E ,

Cements specific requirements within the Slovak eco-labelling process include besides the energy consumption and radionuclides activities limitations the requirements concerned to chromium content. The paper presents a testing of cements produced in the Slovak republic for hexavalent chromium and activities of radionuclides in accordance with the environmental criteria. In addition, the concentrations of barium, and lead were analysed.

The measured concentrations ranged from 0.21 – 3.19 mg/kg, 0.1 to 0.89 mg/kg, and 60 to 140 mg/kg for hexavalent chromium, lead and, barium, respectively. The chromium eco-labelling limit (1.8 ppm) has been exceeded in 28 % of cement samples. Because of the absence of the environmental criteria related to other metals than chromium, the measured concentrations were compared to the limits for barium (II) and lead (II) content in waste water and surface water. Lead (II) content was measured to be less than the maximum allowable concentration for industrial wastewater of 0.4 mg/l. Barium concentrations were measured to be higher than the maximum allowable concentration for industrial wastewaters (2,0 mg/l).

Since no specific requirements are established for the other metals in cement in the Slovak eco-labelling process, the measured concentrations were applied for the proposal of the extended environmental criteria.

[Paper ID614](#)

BUILDING FOR HEALTH; BEYOND SATISFACTION

health; ICF; indoor environmental quality

Kort, HSM. ,



The built environment (BE) for healthcare facilities, demands requirements beyond safety and comfort, because the world is ageing. Ageing adults are more at risk to obtain one or more non-communicable diseases. The WHO-ICF framework illustrates that several contextual factors (environmental and personal) has an influence on people's health condition. In ICF the BE is part of the environmental factors. Environmental factors are not in the person's control. A theoretical approach is taken by using ICF for identifying aspects in the BE which might hinder or support ageing adults. This is done to explore the requirements for building's performance to support ageing adults functioning. In addition, to guide building research and practice thinking about indoor environmental quality conditions for older occupants. ICF distinguish light, sound and air quality as components of environmental factors which influences people's functioning. Functioning is expressed as daily functioning (ADL). ADL expresses activities for daily self-care such as personal care. The BE can be seen as a facilitator qualifier when building related components are such that ageing adults' performance is higher than their capacities for self-care. Therefore BE aspects can also be applied as indoor environmental interventions to maintain or enhance the health condition of ageing adults.

[Paper ID615](#)

SUMMER THERMAL COMFORT COMPLIANCE ASSESSMENT IN APARTMENT BUILDINGS

building simulation; summer thermal comfort; verification methods

Simson, R.S., ,

All buildings in Estonia that have acquired construction permit after the year 2009 have to comply with the minimum requirements for energy performance (Estonian regulation no 68) that regulates the summer thermal comfort with hourly-average temperature excess maximum limit of 150 °Ch of hours over +27 °C. The compliance verification in apartment buildings is required for typical bedrooms and living rooms where overheating is most probable, e.g. rooms with south or west oriented relatively large glazing areas. The temperature calculations are prescribed to be done for each room separately as single zones. In this study we compared measured hourly-average indoor temperature with results from two simulation methods – the currently used single zone method and the whole apartment, multi-zone calculation method. For detailed analysis we selected apartments from 3 apartment buildings in which temperature measurements have been conducted during the summertime period from 1. July to 31. August. For simulations we used energy and indoor climate simulation software IDA-ICE. The study gives an overview whether the multi-zone method is more objective for summer thermal comfort compliance verification in apartment buildings compared to the single zone approach and whether or not its use would be justified.

[Paper ID616](#)

REVIEW OF DERMAL EXPOSURE FACTORS CONCERNING THE PHTHALATES IN CONSUMER PRODUCTS

Consumer product; Dermal exposure; Phthalates

Mizukoshi, A., Azuma, K. dr., Banba, IB dr., Okumura, JO dr., ,



The phthalates contained in consumer products can be readily absorbed into the body through the skin because of their high adsorption properties and lipid solubility, and dermal exposure is therefore of considerable importance in terms of assessing the health risks associated with phthalates. In this study, we have reviewed in detail the factors affecting dermal exposure to the phthalates present in consumer products to allow for an accurate estimation of dermal exposure. Using the factors generated in this study, it was possible to estimate the level of dermal exposure resulting from the phthalates present in consumer products. However, data pertaining to the migration and absorption rates of phthalates from solid products are scarce. Furthermore, these results revealed that the consideration of skin reservoir effects would provide a good simulation of the worst case scenario for dermal exposure to phthalates.

[Paper ID619](#)

THE FEASIBILITY OF VENTILATION TOWER TO ENHANCE CROSS-VENTILATION PERFORMANCE IN A DETACHED HOUSE LOCATED IN URBAN AREA

Computational fluid dynamics; Cross-ventilation; Ventilation rate

Kamioka, H.K. , Kurabuchi, T.K. , Lee, S.L. ,

Cross-ventilation is effective not only for improving the indoor environment of urban housing but also as an energy-saving measure. Cross-ventilation using normal wall openings is difficult because the neighboring ridge space is small in major Japanese cities. To solve this problem, we propose installing a "Ventilation Tower" in a detached house and verify the effect of the tower. We conduct wind tunnel experiments to confirm the effectiveness of the Ventilation Tower as well as the reproductive accuracy of computational fluid dynamics (CFD) analyses. We calculated the ventilation rate and the average wind velocity in the occupied zone in gross building coverage ratios by CFD analyses. The data of CFD analysis correspond to experiment data. At 50% of gross building coverage ratio, the average ventilation rate of tower route is six times as much as that of the wall opening ventilation route. This is because the negative pressure at the tower section is hardly affected by the surrounding buildings. The ventilation rate of the wall opening route significantly decreased as the degree of neighboring building crowding increased. However, the ventilation rate of tower route is ensured regardless of the wind direction and building density.

[Paper ID621](#)

HOUSING, EQUITY, ENERGY AND CLIMATE CHANGE

Climate change; Equity; Housing and energy

Braubach, M. ,



Healthy buildings should not only be healthy by building standards but also be equally accessible to all population groups. Nevertheless, households in less fortunate situations tend to reside in less adequate housing. Based on international and national data, the housing-related equity concerns within the European Union (EU) relate to (a) water supply and sanitary amenities, (b) indoor issues such as overcrowding, dampness and the ability to keep the home warm, and (c) external issues such as noise and access to recreational/ green areas. Specific vulnerabilities are found in relation to equity consequences of current energy and climate change policies, raising questions about their health and equity effects. In conclusion, the data suggest that European housing conditions are not equally distributed; low income and economically vulnerable households are the most disadvantaged; and climate interventions may actually enhance the existing inequality patterns.

[Paper_ID622](#)

THE IMPACT OF INCREASED AIRFLOW RATES ON INDOOR TEMPERATURES OF PASSIVE HOUSE IN THE NETHERLANDS

overheating; Passive house; Ventilative cooling

Barbosa, R. , Loomans, M.G.L.C. , Hensen, J.L.M. , Barták, M

The increasing number of highly insulated and air tight buildings leads to the concern of indoor environment overheating and related comfort and health issues. This can already happen in a temperate climate as found in the Netherlands.

This work studies the ventilative cooling process as a possibility to avoid overheated dwellings. A monitored dutch passive house was modelled in Trnsys and the impact of increasing air flow rates on indoor temperatures was simulated.

The most overheated zone was chosen to be analysed. The ventilation rates were set in accordance with the ventilation system available in the house. Three possible ventilation rates were simulated and the results obtained for indoor temperatures were compared with measured data. The occupancy was estimated in accordance with registred CO₂ levels and the other heat gains were calibrated based on indoor temperature during winter time.

Results indicate that indoor temperatures can be considerably lowered by making use of constant outdoor flow rates during the warm season. However, alternative solutions such as shading devices and passive night cooling might be considered during very warm days, when outdoor temperatures rise above thirty degrees Celsius.

[Paper_ID623](#)

AN INTERVENTION STUDY ON INDOOR AIR POLLUTION SOURCES IN MODERN OFFICE BUILDINGS: RESULTS FROM THE OFFICAIR PROJECT

cleaning products; intervention; Offices

Carrer, P. , Fossati, SF , Piazza, SP , Dell'Ombra, ND , Pasqual, EP , Cattaneo, AC , Cavallo, DC , Mabilia, RM , Bartzis, JB ,



An intervention study has been carried out in modern office buildings to assess the benefit of the replacement of cleaning products in use on EBC pH and endothelial function in 82 office workers, taking into account the role of work related stress (OFFICAIR project). The intervention consisted in replacement of the floor cleaning products in use with a low VOCs and aldehydes emitting one. The intervention consisted in replacement of the floor cleaning products in use with a low VOCs and aldehydes emitting one. Switching to low VOCs and aldehydes emitting floor cleaning products can decrease lung inflammation levels in workers in modern office buildings, in particular in never smoker young adults.

[Paper ID625](#)

ON THE EFFECT OF THE NUMBER OF PERSONS IN ONE OFFICE ROOM ON OCCUPANTS PHYSIOLOGICAL AND SUBJECTIVE RESPONSES UNDER SUMMER CONDITIONS

Perceived control; Performance; Thermal comfort

Schweiker, Ms. , Wagner, aw

Open-space offices are popular among architects and engineers due to their apparent cost-efficiency due to a lower rent and less energy costs per person. Previous studies have shown however that the occupants' satisfaction is less in such offices compared to cell offices with two persons. This could counteract the cost-effectiveness if the productivity of office workers is influenced. In order to reveal further insights into such phenomenon, an experimental study in an outdoor facing climate chamber with two fully equipped office spaces was conducted. 36 subjects worked each during three 8 hour lasting conditions in the offices. The conditions varied in the number of persons in the office from a single office over a two-person office to an office of four people. Physical, physiological, and subjective data was collected together with their behavioural responses. Twice a day, they were prompted to conduct three short performance tests. The results support the hypothesis, that the number of persons in an office inversely affects subjective responses, and stress level. The results hopefully foster a discussion of architectural concepts and their effect on human well-being and performance as important aspect beyond the cost effectiveness.

[Paper ID626](#)

RELATIONSHIP BETWEEN HEALTH SYMPTOMS AND INDOOR AIR QUALITIES OF DIFFERENT AGE GROUPS

Indoor Air Parameters; Indoor Air Quality; Sick Building Syndrome

Bhattacharjee, S. , Wachter, HPW



Poor indoor air quality (IAQ) may lead to various health symptoms of the occupants such as inflammation of eyes and respiratory system. The goal of the study was to find association of the indoor environment qualities with health symptoms related to different age groups. A self-administered questionnaire was used to assess frequency of health symptoms such as headache, sore-throat, etc. and prevalence of self-reported physician-diagnosed health problems such as migraine, asthma, allergy, etc. Indoor air quality parameters were collected following Environmental Protection Agency protocol from four different heavily used spaces by varying age groups in the building over a 2 day period. Additionally 1994–1998 US EPA Building Assessment and Survey Evaluation (EPA BASE) data, a cross-sectional study of workers of varying age groups employed in 100 public and private office buildings across 25 states, was incorporated to analyze differences between the two data collections. Results of one-way ANOVA reported significant difference in health symptom responses between different age groups. Further Pearson's correlation coefficient between reported health symptoms and indoor parameters varied greatly in between different age groups.

[Paper ID627](#)

DEVELOPMENT OF A NOVEL SAMPLING METHOD FOR NICOTINE IN SECONDHAND TOBACCO SMOKE

Nicotine; Tobacco;

Noguchi, M.N. , Yamasaki, A.Y. , Arashidani, K.A , Suzuki, Y.S , Fukushima, Y.F , Tanaka, F.T

Behavior of nicotine in tobacco smoke was investigated, and its sampling method was proposed. Nicotine in the sample tobacco smoke which was collected in a plastic bag and adsorbed gas which was emitted from adsorbed tobacco smoke on the wall of the plastic bag were measured with PTR-MS. Field survey was conducted at an office where is allowed smoking, and nicotine was collected on a glass filter. Nicotine was not detected in the tobacco smoke in the plastic bag, but it was detected in the adsorbed gas. It was thought that nicotine in the tobacco smoke put on the particulates and adsorbed on the wall of the plastic bag. The glass filter collected nicotine in the office air and showed difference of nicotine concentration at smoke area and smoke free area. It was considered that nicotine should be collected by the sampler which is available to collect both of gases and particulate substance.

[Paper ID628](#)

PERCEIVED CONTROL OVER INDOOR CLIMATE AND ITS IMPACT ON DUTCH OFFICE WORKERS

adaptive comfort; individual control; usability of controls

Boerstra, A.C. , Loomans, M.G.L.C. , Hensen, J.L.M. ,



A field study was conducted in nine modern office buildings in the Netherlands. The study focused on perceived control over indoor climate and its impact on satisfaction of building occupants, the incidence of building related (SBS) symptoms and self-assessed performance. The study involved a questionnaire amongst 236 office workers. Statistical analyses were conducted to investigate correlations between combined perceived control over temperature and ventilation on the one hand and satisfaction-, SBS- and productivity-indices on the other. Individual perceived control over indoor climate scores were perfectly normally distributed (using a 7 point scale coded from 1 = no control at all to 7 = full control) with as mean value 3.1 (SD 1.4). Respondents that perceived to have a high amount of control over their indoor climate were considerably more satisfied with their indoor environment. High control respondents also had significant less building related symptoms (BSI(5) 0.94 vs. 0.61). And productivity scores were significantly higher (6.3 %point) in comparison with the low control respondents.

[Paper_ID629](#)

IMPROVING INDOOR AEROSOL EXPOSURE ASSESSMENT BY EXCLUDING NON-OCCUPANCY DATA SEQUENCES

exposure assessment; particles;

Wierzbicka, A. , Bohgard, M , Pagels, J.H. , Dahl, A. , Löndahl, J. , Hussein, T. , Swietlicki, E. , Gudmundsson, A.

For the assessment of personal exposure, information about the concentration of pollutants when people are in given indoor environments (occupancy time) are of prime importance. However this kind of data frequently is not reported. The aim of this study was to assess differences in particle characteristics between occupancy time and the total monitoring period, with the latter being the most frequently used averaging time in the published data. Five indoor environments: an apartment, two houses and two schools, were assessed for particle number and mass concentrations and number size distributions for seven consecutive days during winter. In the apartment median PM_{2.5} mass concentration and particle number concentration during the occupancy time were 17% and 58 % higher, respectively compared to total monitoring period. In both schools, the median values of the PM_{2.5} mass concentration was on average 32% higher during teaching hours compared to total monitoring period. General conclusions on the basis of measurements in the limited number of indoor environments cannot be drawn. However the results indicate that the exclusion of non-occupancy data periods can improve the estimates of particle concentrations and characteristics suitable for exposure assessment, which is crucial for estimating health effects in epidemiological and toxicological studies.

[Paper_ID631](#)

HOUSE OWNERS' EXPERIENCE AND SATISFACTION WITH DANISH LOW-ENERGY HOUSES

Low-energy houses; Occupant satisfaction; Perceived indoor climate

Knudsen, H. , Kragh, J.



The purpose of this study was to identify experiences and satisfaction with new Danish low-energy single-family houses. A questionnaire survey was carried out in the autumn 2013 among owners of newly built energy class 2015 houses. It included i.a. questions on their overall satisfaction, and more specific satisfaction with their perceived indoor climate (temperature, draught, air quality, noise and daylight), and experiences with technical installations and heat consumption. 370 house owners out of 869 answered the questionnaire corresponding to a response rate of 43%. The survey showed an overall high satisfaction with the new low-energy houses, as 93% of the house owners would recommend others to live in such houses. The high satisfaction may, among other things, be due to more than 90% perceive the indoor environment as satisfactory both in summer and winter. 59% found that the energy consumption is as low as expected, while 7% answer that consumption is higher than expected. Compared to previous similar studies problems with technical installations and design have decreased. However there is still a need for focus on the commissioning of the high performance new installations and new designs to achieve both the designed low energy consumption and the desired indoor climate.

[Paper_ID632](#)

ADVANCED AIR DISTRIBUTION METHOD COMBINED WITH DEODORANT MATERIAL FOR EXPOSURE REDUCTION TO BIOEFFLUENTS CONTAMINANTS IN HOSPITALS

air cleaning; hospital environment; local air distribution

Bivolarova, M. P. B. , Chiyomi, C. M. , Melikov, A. K. M. , Zhecho, Z. D. B.

The separate and combined effect of a ventilated mattress and acid-treated activated carbon fibre (ACF) fabric on reducing the exposure to body generated gaseous pollutants in hospital environment was studied. Full-scale experiments were performed in a climate chamber furnished as a single-bed hospital patient room at reduced background ventilation rate of 1.6 air changes per hour. The bed of the patient was equipped with the ventilated mattress (VM) having an exhaust opening from which bioeffluents generated from human body were sucked and discharged from the room. To enhance the pollutant removal, acid-treated activated carbon fibre material was used in some of the experiments in the form of patient's cover. The simulated pollution source was ammonia gas released from the patient's groins. The results show that when using the ventilated mattress the ammonia gas concentration in the room was significantly reduced compared to the concentration measured when the VM was not in operation. The concentration of ammonia gas in the room was 100% removed when the VM operating at 1.5 L/s and the ACF material used as a cover were used together.

[Paper_ID633](#)

PERFORMANCE ASSESSMENT OF A VENTILATED MATTRESS FOR POLLUTION CONTROL OF THE BED MICROENVIRONMENT IN HEALTHCARE FACILITIES

advanced local ventilation; bed microenvironment; pollution control

Bivolarova, M. P. B. , Melikov, A. K. M. , Zhecho, Z. D. B. ,



A new method for minimizing the spread of bioeffluents emitted from hospitalized patients lying in beds was developed and studied. The method consists of a ventilated bed mattress that is able to exhaust the human bioeffluents at the area of the body where generated before spreading around in room. Full-scale experiments were conducted in a climate chamber furnished as a two-bed hospital patient room. A thermal manikin and two heated dummies were used to simulate two lying patients and a standing doctor. The bed with the thermal manikin had the ventilated mattress (VM). The tracer gases CO₂ and N₂O were used to mimic human bioeffluents released from the feet and armpits of the manikin, respectively. The concentration of the tracer gases was measured in six points including the breathing zone of the simulated occupants. The results show that the VM combined with mixing ventilation at 1.5 air changes per hour (ACH) proved to be more effective in reducing exposure to body contaminants compared to mixing ventilation alone at 3 ACH and 6 ACH. The findings also show that the lying position and the size of the local exhaust of the VM affect the efficiency of the mattress to exhaust bioeffluents.

[Paper ID634](#)

EFFICIENT LOCAL PERSONAL COOLING WITH FLUCTUATING AIRFLOWS

air movement; local cooling; thermal comfort

Bakker, L.G. , Hoes-van-Oeffelen, E.C.M. , Hordijk, G.J. , VandenHam, E.R.

Introduction:

Overheating in buildings is an increasingly important issue. Various studies show that local personalized cooling can substantially improve comfort levels while saving energy. Research shows that fluctuating airflows, similar to natural outdoors conditions, are perceived more comfortable compared to continuous airflows.

Methods:

A pilot study was carried out monitoring the user satisfaction of personalized cooling with fluctuating airflows, continuous airflows and without airflows. The airflows, consisting of recirculated room air, were directed from the ceiling to the upper part of the body of the test subjects. Test subjects were able to control the intensity of the air flows by using a user interface. The study was performed in an office space having an air temperature of 28°C.

Results:

During the experiments skin temperatures, airflows and air temperatures were measured. The thermal comfort was evaluated by questionnaires.

Discussion and Conclusion:

The measurements indicate that personalized cooling using an airflow directed to the upper part of the body will improve the thermal comfort significantly. Calculations with a building model showed that increasing the active cooling set point of the room to 28°C can lead to a cooling energy saving of up to 50%.

[Paper ID635](#)

CHARACTERIZATION OF VOLATILE COMPOUNDS EMISSIONS DURING INCENSE BURNING

benzene; formaldehyde; incense

Maupetit, F.. , NICOLAS, MN



Burning incense indoors is resulting in high concentrations of several harmful volatile compounds before emitted pollutants are removed by ventilation. Nevertheless, while emissions from indoorsources (building products, paints, furniture) are continuously lowering due to the implementation of voluntary labelling schemes or mandatory requirements, users of incense products available on the market can be punctually exposed to rather high concentrations of e.g. benzene, toluene, formaldehyde and acetaldehyde. Source control requires relevant testing protocols and standardization of test methods for the characterization of emissions from combustible air fresheners is under progress. This paper presents a comparison of characterization of emissions from incense burning under realistic conditions and under standardized conditions. For most of the tested products and identified compounds, emissions characterized in standardized conditions were higher than in the realistic environment, presumably due to higher burn rates and absence of adsorption on inner surfaces of the test chamber. For routine testing of products, performing only one sampling during combustion is a simple option which can be relevant for product comparison and for the identification of reactive compounds, but it will only provide partial information because a significant amount of pollutants is still present in the emission test chamber after combustion.

[Paper_ID636](#)

COMPARISON OF TWO HUMAN THERMOREGULATION MODELS USING STABLE AND TRANSIENT CONDITIONS

Mutinode model; Thermoregulation; Transient condition

Ogata, O. , Streblow, S , Tanabe, S , Müller, D

In this research, two human thermoregulation models, the JOS-2 model and 33 node comfort model (33 NCM), were compared to determine the effects on predicted values when using different human physiology modeling approaches. Seven test cases, including uniform and stable conditions, and transient steps to hot and cold, were tested in order to observe the performance of the models using various thermal conditions. Predicted skin and core temperatures were compared to each other and to experimental data from human subjects in previously published studies. The comparisons showed that both the JOS-2 and 33 NCM could serve as a good basis for a physiological model used to determine thermal sensation and comfort. A detailed vascular model, such as that implemented in JOS-2, appears to help accurately predict core temperature. Implementation of the hysteresis effect into human thermoregulation models would improve the accuracy of prediction where thermal transient boundary conditions with higher temperature steps are used, especially on the distal portion of the extremities.

[Paper_ID637](#)

THE EFFECT OF ENERGY PERFORMANCE LEGISLATION ON OVERHEATING OF DUTCH OFFICE BUILDINGS: EXPLORATORY STUDY OF FIELD STUDY DATA OF THE LAST 15 YEARS

EPC; Overheating; Thermal Comfort

Beuker, T.C. , Boerstra, A.C.



In order to improve the energy performance of new Dutch buildings, the Dutch government requires every new Dutch building to meet an Energy Performance Coefficient (EPC). The objective of this study was to determine if the increase of energy performance requirements has led to an increased risk on complaints of 'too warm' in existing and newly build Dutch buildings during winter, autumn and spring. For this, field study data from indoor environmental surveys in 38 Dutch offices (4223 building occupants) was analyzed. The results suggest the increased energy performance requirements did not lead to an increased risk on complaints of 'too warm' during winter, autumn and spring in Dutch office buildings constructed before 2009. No such conclusion can be drawn for buildings constructed after 2009 due to lack of data.

[Paper ID639](#)

INFLUENCE OF PUPIL ACTIVITIES AND CLEANING PRODUCTS ON INDOOR AIR QUALITY IN SCHOOLS

cleaning products; pupil supplies; VOC emission

Nicolas, MN. , MANDIN, CM , MAUPETIT, FM , DERBEZ, MD

Pupil supplies and cleaning products need to be documented in order to understand how they could impact on indoor air quality in schools and expose children to high levels of specific contaminants. The aim of this study was to evaluate emissions of volatile organic compounds (VOCs) and aldehydes of different products from these two families.

[Paper ID640](#)

EFFECTS OF THE LOCATIONS OF AIR CLEANER, AIR SUPPLY, EXHAUST, AND HUMAN ON CLEAN AIR AMOUNT INHALED BY THE HUMAN; A COMPUTATIONAL STUDY

Air cleaning; CFD; Human-based ventilation

Abolfazl, Mr. , Ardkapan, Mr. , Rahimi, M ,

A computational study was conducted to enhance thermal comfort in an office using an air cleaner which is capable of cooling its output clean air. The practical idea was to use a thermoelectric device (peltier-element) in an air cleaner unit to in order to simultaneously improve clean air delivery to person's breathing zone and lower the body surface temperature as the target aims of the study. The simulation therefore was exposed to different conditions with regard to air cleaner's flow rate and temperature as well as the manikin and exhaust location to gain a good insight into the flow pattern of the room for a new design.

The target aims showed high sensitivity to air cleaner's flow and the manikin's location, while weakly influenced by air cleaner flow's temperature. In addition it was negligibly affected by the exhaust's location as a result of stratification height formation. It was concluded that to achieve the best clean air delivery to the manikin's breathing zone, the air cleaner flow rate should maintain a fairly higher momentum and 2-4 degrees lower temperature relative to the infiltration flow, and the best location for manikin proved to be under the exhaust location.

[Paper ID641](#)

ADSORPTION CHARACTERISTICS OF SEMI-VOLATILE ORGANIC COMPOUNDS ON SETTLED DUST

Adsorption; House dust; Semi Volatile Organic Compounds (SVOC)



Nomura, K.N. , Kagi, N.K , Namiki, N.N , Kondo, K.K , Tanaka, Y.T , Fujii, S.F

Semi volatile organic compounds (SVOC) are known to be ubiquitous in indoor environments and frequently detected from house dust. It is reported that the levels of SVOC concentration in indoor floor dust have correlations with asthma and allergies of the inhabitants. SVOCs have the tendency to attach to the surface of airborne particle and house dust instead of gaseous matter in the air because of their low vapor pressures. The aim of this study was to investigate SVOC adsorption characteristics by the experiments to adsorb DEHP on test settled particles in various experimental conditions. The dust concentration was analyzed with TD-GC/MS. The amounts of bleed-out on the PVC sheets surface were also measured as the indicator of SVOC emission rate by wiping with quartz filters dipped into methanol. As a result, DEHP concentration is not dependent on the kinds of particle but the surface area. Also the concentration increased in proportion to exposure time, and the adsorption rate is correlated with the amount of bleed-out from material surfaces. It is indicated that the SVOC adsorption of dust on floor materials can be expected by the exposure time, the amount of bleed-out of materials and the surface area of dust particle.

[Paper ID643](#)

OPTIMIZATION OF AIR CURTAIN PERFORMANCE BY PARTICLE IMAGE VELOCIMETRY MEASUREMENTS AND COMPUTATIONAL FLUID DYNAMICS SIMULATIONS: TURBULENCE MODEL VALIDATION

Air curtain; Impinging jet; PIV measurements

Khayrullina, A.A. , Hooff, T.A.J. van, Blocken, B.J.E. , Heijst, G.J.F. van ,

Air curtains can be applied to aerodynamically separate two environments. Air curtains are plane impinging jets at high-Reynolds numbers, preventing the transfer of heat and mass from one environment to another. The performance of an air curtain is called the separation efficiency, which depends on a wide range of jet and environmental parameters, such as jet velocity and turbulence intensity, jet thickness, air temperature differences and pressure differences over the air curtain. This study presents the first results of ongoing research on the optimization of air curtain performance. The first results consist of reduced-scale experiments in a water channel using Particle Image Velocimetry (PIV), and of steady Reynolds-averaged Navier-Stokes Computational Fluid Dynamics (CFD) simulations. The PIV measurements are used to validate the CFD model. Comparison of the experimental results with the results obtained with steady RANS CFD simulations in combination with three different turbulence models showed a fairly accurate agreement.

[Paper ID644](#)

SECONDARY ORGANIC AEROSOL COMPOSITION FORMED FROM VOLATILE ORGANIC COMPOUNDS ON VARIOUS ENVIRONMENTAL CONDITIONS.

indoor environment; secondary organic aerosol (SOA); volatile organic compound (VOC)

Arai, M.A. , Kagi, N. , Fujii, S. , Namiki, N. , Sekiguchi, K. , Azuma, K. , Suwa, Y. , Tamura, H.



The secondary organic aerosol (SOA) formation from volatile organic compounds (VOCs) is an important factor of the indoor pollutions. There have been many reports about particle formations by the reaction of limonene and ozone in indoor environment. However the influence that atmospheric water gives for SOA generation have not yet became clear, also there is no report focused on the SOA composition from limonene and ozone on various environmental conditions. In this study, time dependent SOA composition change was investigated by the experiments using the flow chamber on each humid condition in indoor environment because the time-change of the concentration of the mixture of gas and the particle could be measured. The combinations of concentration of ozone or limonene, humidity and time of the reaction were changed by each experiment, and then each secondary particle generation was observed and the compositions of SOA were analyzed with GC/MS and TOC. As a result, particle diameter and mass concentration, reaction rate, composition of SOA are affected by time dependent change and the concentration. In addition, it was suggested that a chemical reaction also has variable courses according to time dependent change and the ozone and limonene concentration.

[Paper_ID645](#)

A NEW AND IMPROVED LIVING ENVIRONMENT FOR PEOPLE WITH DEMENTIA

dementia; design solution; user-centered

Vermeulen, E.A.F., Hordijk, G.J.

The amount of people with dementia will more than double in the next 25 years, which makes the need to improve their living environment urgent. The aim of the study was to design an improved living environment with a focus on light, that meets the need of elderly with dementia, and thus improve their quality of life.

It was shown that inadequate design and poor lighting conditions played an important role in the behavioral aspects of elderly with dementia. Not only the amount of light (artificial and daylight), but also the view outside is an important aspect.

Freedom, clarity and recognition are important keywords for the design guidelines for people with dementia. Based on these guidelines an ideal living environment for people with dementia was established, where the connection with the outdoor environment and (smart) way finding with natural light was taken as basis of the design.

[Paper_ID646](#)

CFD ANALYSIS OF VENTILATIVE COOLING IN A GENERIC ISOLATED BUILDING EQUIPPED WITH VENTILATION LOUVERS

Air exchange efficiency; CFD simulations; Heat removal effectiveness

Kosutova, K., Hooff, T.A.J van, Blocken, B.J.E, Hensen, J.L.M



This study presents Computational Fluid Dynamics (CFD) simulations of indoor airflow in order to assess the air exchange efficiency and heat removal in a naturally ventilated generic isolated building. The building has a window on both the windward and leeward facade to allow cross-ventilation. First, isothermal steady Reynolds- Averaged Navier-Stokes (RANS) CFD simulations were performed to validate the numerical model using Particle Image Velocimetry (PIV) experiments from literature. Subsequently, non-isothermal steady RANS CFD simulations were conducted to assess the velocity and temperature fields, the air exchange efficiency and the heat removal effectiveness. For both cases a grid-sensitivity analysis was conducted to limit the discretization errors. The CFD simulations were performed for wind direction perpendicular to the building facade with the window opening. Four different window configurations were considered; three with ventilation louvers with different slat angles (0°, 30° and 45°), and one without louvers. The results showed that the configurations with ventilation louvers with an slat angle of 30° and the configuration without louvers have the best performance with respect to ventilative cooling. This configuration had the highest air exchange efficiency (> 51%) and heat removal effectiveness (> 78%).

[Paper_ID647](#)

IMPACTS OF PARTICLE PENETRATION COEFFICIENT AND DEPOSITION RATE IN BUILDING AS A STABLE CONDITION

Deposition rate; Particle; Penetration coefficient

Lee, B.H.L. , Yeo, M.S.Y.

In the indoor environment without mechanical ventilation systems, infiltration becomes the dominant air exchange path. Outdoor particles can infiltrate through the gaps of the building envelope, the windows and doors even when they are closed. Especially when other indoor sinks don't exist, deposition on indoor surface is crucial in controlling indoor particle concentration. This study aims to analyze the impacts of penetration coefficient and deposition rate as a correlation of particle size for the space without ventilation. During the experiments, to keep the space as a stable condition, all openings including windows and door were closed without the operation of air conditioners and the movements of the occupants. The penetration coefficient and deposition rate were determined according to a decay rate constant and the steady-state particle concentration in the transient form of the indoor particle concentration decay profile. The levels of penetration coefficient and the deposition rate were found as a strong relation of the particle sizes. Building envelope and cracks could be a way in filtering the incoming of the outdoor particles from infiltration. Particle deposition also showed a significant sink effect to the indoor particles as they have the same order of magnitude to the air change rate.

[Paper_ID648](#)

CONTROLLING POLLUTANTS DURING NEW CONSTRUCTION TO REDUCE EXPOSURE UPON OCCUPANCY

Chemical; Construction; Particulate

Grimes, CEG. ,



If reduction of exposure to pollutants – by removal – from existing construction is more effective than isolation, reduction, or filtration, then it is logically true that avoidance by removal during construction will be more effective than isolation, reduction, or filtration after construction; and certainly more so than during occupancy. A custom home in Carmel, CA, USA, was built according to this principle in 2003 and 2004 using only non-toxic or the least-toxic building materials available. Control of “dust” during construction was attempted by specifying work practices. Two similar methods of measurements were conducted prior to occupancy to determine the relative success of the preventive actions. The objective was to observe whether these actions could actually be implemented, and if so, if results were measurable.

[Paper ID649](#)

LAWS, REGULATIONS AND THEIR INTERPRETATION: THE CASE OF HIGH INDOOR TEMPERATURES IN GERMANY

Indoor environmental quality; litigation; overheating

Hellwig, RTH. , Dr. Bux, K

In the nineties and noughties a number of law suits on high indoor temperatures led to misinterpretation and to a strict interpretation of the then in force rule on workplace temperature (ASR 6/1.3, ASR 6). Based on DIN 1946-2 a district court in 2003 concluded that “...the room temperature must not exceed 26°C.” and at outside temperatures of 32°C the indoor temperature must be 6°C lower. The rule was further developed. The revised version defines the requirements for an acceptable elevated room temperatures in the case of high outside temperatures using a step model following the principle of the adaptive approach. In the daily occupational safety and health practice the step model proved to be applicable because the new rule contains concrete guidance on how to proceed where there are temperatures between the comfort temperature range and the temperature defining work in heat. Whereas in the nineties courts assigned the task of meeting these requirements to landlords and property developers, recent court decisions assigned this task to the tenant of commercial premises. The tenant has to solve the conflict between providing a healthy workplace and the premises that may not fulfil these requirements even though it complies with the building legislation.

[Paper ID650](#)

THE INFLUENCE OF THE INDOOR ENVIRONMENT ON SLEEP QUALITY

indoor air quality; sleep quality; thermal environment

Urlaub, S. , Grün, G , Foldbjerg, P , Sedlbauer, K



A good sleep is essential for human well-being and for a good performance at work or in school. The physical environment, especially the thermal conditions and the indoor air quality, is important for a good sleep. Wake people are influenced by these two parameters in many different ways, so one may suggest that sleeping people are susceptible for disturbances due to a bad physical environment as well. An extensive literature search identified 24 scientific studies in this field, only six of those deal with indoor air quality. Room temperature above thermoneutrality seems to influence sleep quality in the sense that slow-wave sleep, REM-sleep and total sleep time are reduced. The studies about indoor air quality showed no trends to influence sleep quality. As these studies form a rather thin basis for definite correlations much more research is required especially in the field of indoor air quality.

[Paper_ID651](#)

PSYCHOACOUSTIC AND PEOPLE-CENTRED APPROACH

acoustic comfort; office planning; Psychoacoustics

Oseland, N. , Hodsman, P.

Whilst it is widely recognised that acoustics is an interdisciplinary science, many architectural acousticians have a physics or engineering background and the approach to mitigating noise is mostly, but not entirely, focussed on physical solutions. This report is predominately based on a literature review of nearly 200 research papers. The emphasis is placed predominately on psychophysical research papers rather than pure acoustic ones. The perspective is a psychoacoustic and people-centred approach focussing on psychology – perception, attitudes, mood, personality and behaviour. The literature review establishes that the key issue in the workplace is the distraction caused by perceived noise as opposed to the interference from the background sound level. In particular, distraction from noise results in loss of concentration/focus and memory/recall which in turn results in loss of office worker performance. Because noise perception is dependent on personal factors, it means that different office workers will react differently to the same acoustic conditions in their workplace. So resolving noise distraction needs to account for individual differences and not assume that a single physical acoustic solution will work for all office occupants.

[Paper_ID652](#)

CONCRETE CORE ACTIVATION AND SUSPENDED CEILINGS: DESIGNING FOR COMFORT, ENERGY EFFICIENCY AND GOOD ACOUSTICS

Acoustics; Concrete core activation; Thermal capacity

Vercammen, M.L.S. ,



Thermally activated concrete slabs (concrete core activation) offer an interesting possibility to control the indoor climate. The important drawback of thermally activated floors is the acoustics. To control sound levels in a space, sufficient sound absorbing material has to be applied. For practical reasons, also cost efficiency, this sound absorbing material is often realized as a sound absorbing suspended ceiling.

Generally sound absorbing material is also thermally insulating, which will have a considerable negative effect on cooling and heating capacity. To show the influence of the configuration of ceiling elements on the sound absorption, a series of measurements have been performed on a mineral wool ceiling. To determine the influence of the free hanging ceiling on thermal capacity of the activated concrete slab, a mock-up has been constructed in a climatic chamber.

From laboratory studies, both regarding acoustic and climatic behaviour, it appears that both reduction of the sound absorption and cooling capacity is less than proportional to the surface of the ceiling elements. The thermal capacity is dominated by the convection air flow between ceiling elements and floor slab. Depending on the type of ceiling material and configuration, an optimum for thermal capacity and sound absorption can be obtained.

[Paper ID653](#)

INDOOR ENVIRONMENT QUALITY: LEGISLATION AND REGULATIONS IMPLEMENTATION IN THE UNITED KINGDOM

Indoor environmental quality; legislation; mould

Sassi, P. ,

This workshop presentation reviews current UK legal framework, legislation and court cases related to indoor environmental quality. Currently, limited legislation exists that directly relates to indoor environment quality. However, cases of personal injury resulting from poor indoor environment quality are being brought to court on the basis of breach of contract relating to regulations that stipulate in particular fitness for purpose. With more evidence for a link between personal injury and indoor environment quality it can be expected that legal cases relating to poor indoor environment quality will increase.

[Paper ID654](#)

IEQ PERFORMANCE GAPS: FAILURE MODES, LITIGATION RISKS, AND THE NEED FOR QUALITY.

IEQ; performance gap; quality

Tuohy, P.G. ,

There is much evidence that current building industry process does not deliver the intended outcomes (1). Performance gaps exist including IEQ failures which have resulted in litigation. These performance gaps and litigation are likely to increase due to the move towards more advanced buildings and systems, changes in local weather, and the increasing availability and use of post occupancy performance monitoring. While there are many initiatives aimed at improving industry process, none of these directly address the quality issue (2). It is proposed that a quality systems approach similar to that of other more performance sensitive industries could provide a solution.

[Paper ID655](#)

THE CHALLENGE OF MEETING BOTH ACOUSTIC AND THERMAL COMFORT IN 21ST CENTURY SCHOOL



Classrooms, Reverberance; Sound, Absorption; Thermal Mass

Klamerek, G. , Campbell, C. , Svensson, C. , Nilsson, E.

The benefits of 'thermal mass' in stabilizing temperature for thermal comfort and reducing building energy consumption for sustainable green buildings are well documented. However, when exposing the concrete soffit for thermal purposes it is then not possible to have a fully covered sound absorbing suspended ceiling in classrooms for acoustic comfort. In turn, this potentially compromises the achievement of good acoustic comfort while still utilizing the thermal mass of the exposed soffit. For this paper we measured a classroom configuration with free hanging sound absorbing units and wall absorbers instead of a fully covering traditional suspended ceiling. We looked into solving the low frequency imbalance - a potential negative consequence of not having a full suspended ceiling - with an enclosed void which can trap the low frequency sound (125Hz) which can build up and interfere with the important speech frequencies. We looked at the challenge of optimizing the acoustic coverage range without affecting the thermal comfort. We also wanted to improve the balance of the potentially negative low frequencies to achieve good speech communication and acoustic comfort for all students and teachers, while also providing an inclusive acoustic environment for sensitive listeners.

[Paper ID656](#)

NATIONWIDE ESTIMATES OF SEMI-VOLATILE ORGANIC COMPOUNDS CONCENTRATIONS IN SETTLED DUST AND SUSPENDED PARTICLES IN FRENCH DWELLINGS

airborne particles; settled dust; SVOCs

Mandin, CM. , Mercier, FM , Lucas, JPL , Ramalho, OR , Blanchard, OB , Bonvallot, NB , Raffy, GR , Gilles, EG , Glorennec, PG , Le Bot, BLB , Le Bot, BLB ,

INTRODUCTION: Semi-volatile organic compounds (SVOCs) are of concern due to their health effects and to the widespread exposure through different environmental media and pathways. The objective of this study was to assess the concentrations of a large group of SVOCs both in floor settled dust and on airborne particles in dwellings.

METHODS: Vacuum cleaner bags were collected during a nationwide survey carried out in French dwellings where at least one child aged 6 months to 6 years lives (2008-2009). PM10 were sampled on Teflon filters over one week in the living-room during a nationwide survey carried out in a representative sample of the housing stock (2003-2005).

RESULTS: In settled dust, 32 SVOCs out of 48 were detected in more than half of the dwellings. Similarly on PM10 35 SVOCs out of 66 were detected in more than half of the dwellings. The most concentrated compounds in both media were phthalates, polycyclic aromatic hydrocarbons (PAHs), and bisphenol-A. Additionally, permethrin, synthetic musks, and BDE-209 were among the most concentrated compounds in settled dust, and triclosan on PM10.

CONCLUSIONS: The concentrations appeared to be in the same order of magnitude as in other countries, except for permethrin, DiBP, and bisphenol-A in settled dust.